Developmental Changes in Reward Processing and Sensitivity to Social Ostracism

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Abstract

Adolescence is characterized by a myriad of social, emotional, and cognitive transitions. Most notable are increased risk-taking behavior, thought to result from heightened reward sensitivity, and increased importance of peer relationships, which may be enabled by heightened sensitivity to social information. These factors may converge to increase the risk of anxiety and depression in adolescence. The goal of the current study was to examine risk and reward sensitivity, responses to positive and negative social information, including social ostracism, and symptoms of anxiety in three age groups: children, adolescents, and adults. 158 participants completed a social or nonsocial gambling task, were socially ostracized by peers on the Internet, and then completed the same gambling task to examine changes in risk-taking behavior. Results are discussed in terms of general developmental trends on the social and nonsocial gambling tasks, links between anxiety and risk-taking, and links between emotional sensitivity to ostracism and change in risk-taking in each age group. A number of unique trends were found in the child and/or adolescent age group, including positive correlations between anxiety and risk-taking and sensitivity to ostracism and increased risk-taking. However, adolescents did not show heightened risk-taking or sensitivity to social information in general, relative to children and adults. Findings speak to the importance of testing multiple age groups in studies of adolescent development, and support the notion that *interactions* between social sensitivity and reward sensitivity may help to explain the risk for internalizing problems in adolescence.

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Chapter 1: Introduction

General Introduction

Scientific interest in the developmental changes characterizing adolescence has exploded in the past decade. Adolescence is the transition from childhood to adulthood, when individuals begin to separate from the family, engage in more meaningful peer relationships, and develop their personal identity (e.g., Arnett, 1999). This phase of life is characterized by profound biological, social, and environmental changes. Biologically, adolescence is defined by the onset of puberty and extends through the completion of pubertal development. Socially, adolescence is characterized by increased separation from parents, increased interaction and deeper relationships with peers, and the development of romantic interest (Nelson, Leibenluft, McClure, & Pine, 2005). In Western societies, a large number of extrinsically imposed changes define adolescence as well: changing schools, increased academic and household responsibilities, and increased freedom in one's daily routine.

It has recently been observed that a consequence of these converging biological, social, and environmental transitions in adolescence is, in some cases, an increase in risky behavior (Arnett, 1999). A large body of research suggests that adolescents may be predisposed to make riskier decisions than younger and older individuals, at least in certain contexts. A major focus of recent research on adolescence has been attempts to explain the "aberrant" and "risky" behavior in which some adolescents engage: use of illegal drugs and alcohol, unprotected sex, unsafe driving, and other forms of dangerous risk-taking. In addition to real-life observations, a higher propensity to engage in risky behavior among adolescents has also been demonstrated in laboratory tasks (e.g., Crone

& van der Molen, 2007). To explain this developmental phenomenon, researchers have turned to brain development, suggesting there is an imbalance between regions that subserve emotional reactivity and reward processing, which are more active during adolescence, and later-maturing regions that subserve emotion regulation and self-control (Steinberg, 2010).

Although this popular narrative on adolescence, brain development, and risk-taking is widely supported empirically, there is considerable variability in the level of risky behavior in which individuals engage (Galvan et al., 2006). Furthermore, it appears that only a small subset of adolescents engage in most of the risky behavior that is most concerning to scientists, parents, and educators (Romer, Betancourt, Brodsky, & Giannetta, 2012). In fact, internalizing problems in adolescence may be just as prevalent, if not more so, than the externalizing behaviors that have garnered so much attention. Multiple studies show that symptoms and diagnoses of anxiety and depression rise substantially during this period (Angold, Costello, & Worthman, 1998; Sontag & Graber, 2010). Although internalizing problems may be less outwardly visible than externalizing problems, they are just as distressing to individuals who experience them.

Only in the past few years have researchers begun to focus on the mechanisms underlying this increase in internalizing during adolescence (Forbes & Dahl, 2012). Interestingly, studies examining this topic suggest that some of the same neurodevelopmental changes that underlie increased propensity towards risk-taking/externalizing, such as reward sensitivity, might also explain increased internalizing in this stage of development (Davey, Yucel, & Allen, 2008; Forbes et al., 2006). In addition, both contextual social changes and changes in social information processing capabilities may also place some adolescents at risk for internalizing problems, for example by increasing their perception of social evaluative threat (Silk et al., 2012).

Adolescence may be a sensitive period during which learning in the social domain is accelerated (Blakemore & Mills, 2014), due to both contextual and intrinsic mechanisms. In addition to neurobiological predispositions to separate from the family and engage more with peers (Nelson et al., 2005), changes in social context, as children move from elementary school to middle and high school, require adolescents to adapt to new peer groups. Thus, increased sensitivity to social information is likely beneficial, allowing adolescents to make smooth transitions to new social groups. However, for various reasons, some individuals flounder during adolescence, failing to find their place within these new peer groups. This developmental stage is therefore a period of both vulnerability and opportunity. The current study addresses the mechanisms through which adolescents might flounder or flourish by investigating developmental changes in risk and reward processing, social information processing, and internalizing symptoms, as well as interactions between these factors. This holistic approach should result in a more nuanced understanding of the factors that lead to internalizing problems in adolescence, as well as potential directions for intervention.

Risk and Reward Processing in Adolescence

Adolescence is characterized by an increase in novelty seeking and risk-taking behaviors (Arnett, 1999). In past decades, explanations for this increase in risk-taking behavior tended to focus on "immature" cognitive control/self-regulatory skills in this age group relative to adults (Johnson, Blum, & Giedd, 2009). More recently, the focus of research has shifted to a combination of immature regulation ability *and* greater drive for reward in adolescence: the "dual systems" model (Steinberg, 2010). According to this idea, executive function and emotion regulation systems, subserved by the prefrontal cortex, mature in a linear fashion from childhood to adulthood while the activity of reward systems follow an upside-down U-shaped curve, peaking in adolescence. In other words, at the point in development when reward sensitivity is highest, emotion regulation capacities are not yet fully mature, a combination that may contribute to the adolescent-specific increase in risky behavior. Both behavioral and functional neuroimaging data in adolescents tend to support this view (Steinberg, Albert, Cauffman, Banich, Graham, & Woolard, 2008; Casey, Getz, & Galvan, 2008).

Researchers often examine reward processing in the laboratory using affective decision-making tasks that simulate gambling. In these paradigms, individuals who are able to learn the most advantageous strategies for long-term gains reap the greatest rewards. For example, the widely-used Iowa Gambling Task involves four decks of cards that differ in the magnitude and frequency in which rewards and punishments are given, as well as in their long-term advantage across the task. In one variation of this task, adolescents were been found to be more approach oriented than pre-adolescents or adults: they played increasingly more from advantageous decks, but not less from disadvantageous decks, over the course of the task (Cauffman et al., 2010). This pattern suggests they are more sensitive to rewards, but not more sensitive to punishment, than other age groups. Adolescents have also been shown to activate the reward-sensitive nucleus accumbens more than children or young adults during a similar task, and to activate the orbito-frontal cortex, which appears to be involved in risk and reward evaluation, less (Galvan et al., 2006). Findings from both these studies support the notion of dual systems.

However, the study of risk-taking with affective decision-making tasks is complicated by at least two factors. First, risk-taking by definition involves both potential reward and punishment (Ernst et al., 2009). Thus, both desire for reward *and* risk aversion may influence behavior and neural activation in gambling tasks, and it is difficult to disentangle the two. For example, if an individual selects an advantageous deck on the Iowa Gambling Task, they may be trying to obtain a reward, avoid a punishment, or both. Second, reward processing and cognitive control interact to influence performance on these incentive-driven tasks: adolescents have been shown to activate regulatory regions *less* than adults in these tasks; however, *increased* activation in these regions is correlated with improved performance and fewer risky decisions (Eshel, Nelson, Blair, Pine, & Ernst, 2007). Therefore, it can be difficult to determine whether an age-related decrease from adolescence to adulthood in risk-taking behavior is due to increased reward sensitivity in adolescence or to decreased top-down regulation from frontal regions. For this reason, the inclusion of a child group in studies examining these questions is important: because we know that regulatory skills increase from childhood to adolescence (e.g., Lamm, Zelazo, & Lewis, 2006), greater reward sensitivity in adolescents versus children *cannot* be explained by greater top-down regulation in children. Nevertheless, many studies investigating this topic include only adolescent and adult age groups.

Another limitation of this line of research pertains to the tasks used to study risk-taking in adolescence. Many affective decision-making tasks rely on monetary outcomes divorced from any social information to measure reward sensitivity. However, if adolescents are particularly sensitive to social information (Nelson et al., 2005), one might predict that social cues may change adolescents' motivation during these tasks. A particularly salient social factor that appears to influence adolescents' behavior in these tasks is the presence of peers. The first study to examine this "social facilitation" effect (Gardner & Steinberg, 2005) demonstrated that peer presence in a simulated driving task increased risk-taking in adolescents disproportionately compared to children and adults. Furthermore, in an fMRI study using the same task with children, adolescents, and adults, only adolescents activated reward-processing regions (ventral striatum) more strongly in the presence of peers (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011). In parallel with these laboratory findings, most real-world risk-taking in adolescence takes place in groups (Steinberg, 2008). The unique salience of peers to adolescents—perhaps due to a preoccupation with peer evaluation--could explain this phenomenon. Multiple studies show that adolescents can reason adequately about the consequences of risky behaviors in the abstract (Steinberg, 2008), but the possibility of peer evaluation might add emotional salience to otherwise straightforward situations. Peer approval and social standing are particularly important to adolescents (Brown & Larson, 2009), and it is therefore important to include social factors in models of adolescent behavior and brain development.

A model of adolescent reward processing that attempts to incorporate social and emotional factors been proposed by Ernst, Romeo, & Anderson (2009). Their triadic model attempts to explain motivated or goal-directed behavior in adolescence, focusing on the limbic system (amygdala), the reward system (striatum/nucleus accumbens), and the regulatory system (PFC). Their model differs from the dual systems model by emphasizing the amygdala/avoidance system, which, like the reward system, may show heightened activity in adolescence. For example, adolescents may take more risks in the presence of peers because they are motivated to avoid the social punishment of being judged negatively, rather than because their drive for reward is increased. Research showing enhanced amygdala activation in response to emotional faces in adolescents compared to adults (Guyer, Mcclure-tone, Shiffrin, & Nelson, 2009) supports the notion that the limbic system, which responds particularly to social information (Adolphs, 2003), influences adolescent motivated behavior.

Sensitivity to Social Information in Adolescence

Evidence that adolescent risk-taking behavior is more heavily influenced by the presence of peers than that of younger children and adults (Gardner & Steinberg, 2005) supports the notion that adolescence is characterized by a "social re-orientation" (Nelson et al., 2005). As individuals transition from childhood to adolescence, they become more sensitive to social information, particularly information related to social evaluation by peers (Somerville, 2013). Both rewards (e.g., peer acceptance) and punishments (e.g., peer rejection) that are social in nature may become more salient in adolescence, facilitating an increased motivation to engage with peers (Nelson et al., 2005). There is also evidence suggesting that adolescents' heightened sensitivity to social information may extend to relatively abstract social cues: In addition to the presence of real live peers, more low-level social stimuli such as photographs of emotional faces have been shown to elicit different neural and behavioral responses in adolescents compared to other age groups (Guyer et al., 2009; Hare et al., 2008). For example, adolescents show heightened amygdala activation to fearful faces, relative to other age groups, in certain contexts (Hare et al., 2008; Monk et al., 2003) and greater interference from happy faces during a cognitive control task (Hare et al., 2008). These findings suggest that both positive and negative emotional faces may be more salient to adolescents than to other age groups.

In addition to enhanced affective processing of social information in general, adolescents show increased sensitivity to feedback in social situations, particularly when peers are involved. For example, Gunther Moor and colleagues (2010) showed adolescents and adults pictures of unfamiliar peers, asked participants to predict whether each peer liked their own picture, and then displayed feedback on the peers' decision. They found that adolescents' subsequent predictions were more affected by negative peer feedback than were those of adults. Guyer and colleagues (2009) developed a virtual "chatroom" task to examine more complex peer interactions. In this task, 9-17 year-old female participants rated how interested they would be in chatting about a given topic with unfamiliar peers. Two weeks later, they were asked to anticipate how high-interest and low-interest peers would evaluate them during an fMRI scan. Researchers found that activation in both limbic and reward-processing regions for high-interest vs low-interest peers increased as girls entered adolescence. In sum, both behavioral and neural measures of responses to social feedback appear to be heightened in adolescents relative to adults and/or children.

A recent study showed that adolescents also experience heightened embarrassment relative to adults and children when they believe that they are being evaluated by a peer (Somerville et al., 2013). Embarrassment is a self-conscious emotion, directly related to inferences about others' perceptions of oneself. Examining behavioral, physiological, and neural measures of embarrassment in individuals age 8-23, Somerville and colleagues (2013) found that adolescents reported greater levels of embarrassment in the scanner than children and young adults when told they were being watched through a camera feed by a peer in the next room. The age-group difference was not found when participants were told the camera was turned off. Corroborating the self-report data, adolescents also showed larger skin conductance responses than the other age groups in the "camera on" condition. Finally, adolescents showed greater medial prefrontal engagement in the "camera on" condition than children and adults, which could be indicative of more self-reflective processing and/or more mental-state reasoning in adolescents when they think a peer is watching them.

In addition to experiencing greater affective responses in social situations, adolescents may be less efficient at regulating their emotions than adults (Silvers, McRae, Gabrieli, Gross, Remy, & Ochsner, 2012). The consequences of reduced emotion regulation may be particularly salient in social situations given adolescents' fears of being evaluated negatively by peers (Westenberg et al., 2007). In certain situations, reduced emotion regulation among peers could result in risky and impulsive behavior, which has been studied extensively (e.g., Gardner & Steinberg, 2005; Albert, Chein, & Steinberg, 2013). In other situations, deficient regulation of negative emotions, such as fear of peer rejection, could facilitate avoidance of interacting with peers. In other words, a teen may be more likely than a child or adult to engage in risky behavior due to peer pressure and also to be devastated when she is rejected by peers. In both cases, there is a failure to regulate one's emotional response during a perceived high-risk situation. Although in the former case, some (Steinberg, 2008) favor the interpretation that reward drive is ramped up in the presence of peers, it is also possible that fear of negative peer evaluation drives risky behavior among adolescents.

Peer rejection does appear to cause more acute suffering in adolescents than in other age groups. In a study (Sebastian, Viding, Williams, & Blakemore, 2010) in which participants were included and subsequently ostracized by “peers” on the Internet during a ball-tossing game (Cyberball), adolescents rated their mood as lower and their anxiety as higher after the ostracism condition, while adults did not show significant differences between ratings after inclusion and ostracism conditions. A manipulation check indicated no age-group differences in the extent to which subjects felt included or excluded during the game, meaning that increased negative mood and anxiety in the adolescents did not arise simply because they felt more excluded than adults. Rather, they seemed to be more affected emotionally by the same exclusion experience. This increased reactivity to social rejection could have negative social consequences for some adolescents, resulting in social anxiety and other mental health problems. However, further research is needed to clarify how and when a normative increase in sensitivity to social rejection becomes problematic.

Internalizing Symptomatology in Adolescence

It is well known that susceptibility to peer influence in adolescents can result in increased engagement in risky behavior and externalizing problems such as alcohol and substance abuse (e.g., Allen, Porter, & McFarland, 2006). Susceptibility to peer pressure could result in part from heightened sensitivity to social rejection in adolescence, and both of these factors have been linked to internalizing symptomatology (Allen et al., 2006; Sebastian et al., 2010). Internalizing problems are characterized by the excessive experience of inwardly directed negative emotions such as sorrow, guilt, fear, and worry (Waxler, Dougan, & Slattery, 2000). The incidence of internalizing disorders such as anxiety and depression rises sharply during adolescence. Though less than 1% of children under age 12 have ever met criteria for major depression, approximately one in five individuals has experienced this disorder by age 18 (Kessler et al., 2001).

Only recently have scientists begun to examine the developmental origins of internalizing disorders (Waxler et al., 2000). Research addressing this issue tends to emphasize a diathesis-stress model, wherein biological vulnerability is exacerbated by psychosocial stress, resulting in a psychological disorder. Adolescence is characterized by high levels of psychosocial stress, so it is not surprising that anxiety and depression often are first diagnosed during this stage of development. Furthermore, emotional reactivity and negative affect are heightened during adolescence. Surprisingly, only in recent years have emotional processes been emphasized in the development of internalizing problems (Waxler et al., 2000). Traditionally, researchers have studied more cognitive processes, such as the tendency to ruminate in depression (Nolen-Hoeksema, 2000) and attentional biases to threat in anxiety (Bar-Haim et al., 2007). But examining the *development* of internalizing yokes together emotional and cognitive processes, as both undergo transitions in adolescence: emotional reactions become stronger, particularly in social situations, and social cognitive abilities continue to mature, allowing individuals to reason about—and to ruminate on--the mental processes of other people. Due to the combination of increased salience of social experiences and the ability to reason in a sophisticated manner about others' evaluations of oneself, negative social experiences in adolescence might especially increase the likelihood of developing internalizing problems.

Indeed, there is strong evidence to suggest that peer rejection in adolescence affects subsequent internalizing symptomatology. Social exclusion in adolescence has been found to predict subsequent social anxiety (Vernberg, 1990), as well as lifetime risk for mood and anxiety disorders (Lev-Wiesel, Nuttman-Shwartz, & Sternberg, 2006). Furthermore, there is evidence that internalizing and negative social experiences reciprocally influence one another over time, such that psychologically distressed adolescents also elicit more exclusion and/or victimization from their peers (Carter, Garber, Ciesla, & Cole, 2006). Individual factors such as rejection sensitivity play an important role linking negative social experiences to internalizing in both children and adolescents (Sandstrom, Cillessen, & Eisenhower, 2003). One mechanism through which social exclusion may lead to internalizing symptoms is the individual's attributions of ambiguous peer behaviors as critically self-referent. In one study, adolescents who responded to ambiguous scenarios, such as getting bumped by someone and dropping one's books, as reflecting inadequacy in themselves were subsequently more prone to experience depression, social anxiety, and loneliness (Prinstein, Cheah, & Guyer, 2005). Thus, some adolescents will be more affected by aversive social experiences than others, and more likely to develop depression and/or anxiety as a result of such experiences.

Depression and anxiety are often comorbid, especially in adolescents (Garber & Weersing, 2010); furthermore, anxiety in childhood/early adolescence is one of the strongest predictors of depression in later adolescence (Beesdo et al., 2007; Silk et al., 2012). These disorders share both common and distinct features. Depression has been characterized by anhedonia, or a loss of affective motivation, which seems to be manifest primarily in reduced drive for reward: Depressed individuals tend to show reductions in approach/reward-seeking goals, but may not differ from healthy individuals in terms of avoidance/risk-avoidant behaviors (Dickson & Moberly, 2010). In laboratory tasks, depressed individuals also show greater attentional biases toward negative information than controls (Gotlib, Krasnoperova, Yue, & Joorman, 2004). Perturbations in reward- and regulation-related brain activity that could reflect anhedonia and failure to regulate negative emotions have also been reported in depressed individuals (Forbes, 2009).

In some respects, anxiety disorders are characterized by differences from depression, predicting *increased* avoidance behavior, but intact approach behavior relative to healthy individuals (Dickson & MacLeod, 2010). Anxiety has been described as an imbalance in the fight or flight system that subserves approach or avoidance behaviors, such that motivation is biased towards flight/avoidance (Gray, 1991). In laboratory tasks such as the dot-probe, anxiety disorder patients show greater attentional biases towards threatening cues than healthy individuals (Bar-Haim et al., 2007). Heightened physiological and neural responses in anxiety disorder patients have been found most consistently with *ambiguously* threatening cues, including emotional faces (Lissek et al, 2008), and in circumstances in which identifying the negative valence of these cues is irrelevant to the task (Straube, Kolassa, Glauer, Mentzel, & Miltner, 2004). These findings could reflect a failure to engage regulatory mechanisms to ramp down affective responses to benign cues, resulting in hypervigilance to threat. In contrast, cues that are obviously threatening and/or task-relevant may elicit high levels of processing in both anxious and healthy populations. Thus, one commonality between anxiety and depression appears to be deficits in emotion regulation.

As discussed earlier, the failure to regulate emotions and behavior is also one factor thought to explain increased emotional reactivity and risk-taking in adolescence. Thus, it seems plausible that the same systems that facilitate these normative changes in adolescence are also linked to the rise in internalizing symptomatology during this stage of development. At the neural level, there are parallels between networks that are implicated in internalizing disorders and those that subserve emotion regulation and undergo remodeling during adolescence (Anderson & Teicher, 2008). While attempting to regulate negative emotions, both adolescents and adults with depression tend to show reduced prefrontal activity relative to healthy controls (Johnstone, Van Reekum, Urry, Kalin, & Davidson, 2007; Perlman et al., 2012). These results parallel behavioral findings showing that young adolescents are less successful at regulating their emotions in response to negative *social* stimuli than adults (Silvers et al., 2012).

In internalizing disorders, decreased prefrontal activation tends to be accompanied by increased limbic activation in the context of negative or threatening cues, also similar to normative patterns in adolescence. The main difference is that in healthy adolescents, primarily brain regions that process appetitive stimuli (i.e., striatum) are more active, while anxiety and depression are linked to hyper-reactivity in regions that process aversive stimuli (i.e., amygdala). However, in certain contexts, amygdala responses to social stimuli in healthy adolescents are increased relative to other age groups (Hare et al., 2008; Monk et al., 2003). In addition, abnormal reward-related activation in depressed adolescents has been reported (Forbes et al., 2009). These overlaps between brain circuitry involved in the normal transition to adolescence and in internalizing problems could go far in explaining the increased incidence of anxiety and depression in adolescence. It has been even proposed that a failure to obtain the normal elevated levels of reward drive that characterize adolescence is related to the onset of depression in this age group (Forbes & Dahl, 2012).

In addition to reward processing, patterns of threat processing unique to adolescents may make them more susceptible to internalizing problems than adults. A study that used a social fear conditioning paradigm (pairing a neutral face with either a scared face + scream or another neutral face) found that healthy adolescents showed higher galvanic skin conductance responses during conditioning, less discrimination of fear and safety cues (reporting relatively high levels of subjective fear even for safety cues), and increased limbic activation to threat cues (Lau et al., 2011) relative to adults. These findings are largely in the same direction as what has been reported in fear-conditioning studies for adults with anxiety disorders, suggesting increased acquisition of fear learning but impaired discrimination for safety cues (Lissek et al., 2005).

In sum, the onset of anxiety and depression in adolescence has so far been chalked up to mostly external stresses in adolescents' lives: changing schools, going through puberty, romantic relationships, increased responsibility and expectations. But we know very little about why these changes affect some individuals differently than others, and even less about the differential factors that lead to anxiety versus depression versus externalizing problems. Individual differences in psychological factors that are known to undergo major transitions in adolescence, including threat avoidance, reward-seeking and sensitivity to social information, as well as interactions between these factors, are likely to be important predictors for the development of internalizing problems. The current study addresses how these psychological factors may be associated with vulnerability to anxiety in early adolescence.

Interactions between Social Experience and Risk-Taking

Although changes in risk and reward processing, sensitivity to social experience, and increased risk of anxiety and depression in adolescence are well documented, few studies have examined how these factors link together. However, a recent study combined the Cyberball ostracism paradigm (Williams et al., 2000) with the Stoplight driving task (Steinberg et al., 2005). In this study, adolescents were led to believe that the peers who had just excluded them were watching them perform (Peake et al., 2013). Adolescents showed increased risk-taking following ostracism, which was more pronounced among those who were low in resistance to peer influence. Although these results could reflect *increased* reward-seeking behavior following social ostracism, the presumed presence of peers complicates their interpretation. For example, some adolescents may have increased their risky-decision making because they wanted to perform better than the peers who had just excluded them (reward-seeking) or because they were afraid the peers would make fun of them if they did badly (punishment avoidance).

On the other hand, researchers have hypothesized that a normative increase in social reward seeking combined with negative social experiences in adolescence (e.g., peer rejection) could lead to depression through *dampening* reward systems over time (Davey, Yucel, & Allen, 2008). According to this model, increased desire for social reward that is repeatedly frustrated leads to a gradual down ramping of reward systems, so that systems that were previously overactive become underactive. Supporting the second part of this model, depression or risk for depression has been associated with less reward-related activation in response to appetitive stimuli in adults and children (Forbes et al., 2006; Monk et al., 2008). With this model in mind, the current study combines an incentive-based task with the Cyberball paradigm to investigate individual and age group differences in typical development.

Current Study

The goal of my dissertation is to elucidate the links between risk and reward processing, sensitivity to social information, and sub-clinical internalizing symptoms across development. This study extends the findings of Peake and colleagues (2013) by examining multiple age groups utilizing a different incentive-based task and different social manipulation, and examining internalizing symptomatology, including social anxiety. This study fills gaps in the literature on adolescent social-emotional development by linking together factors that have been designated as important and/or highly prevalent in adolescence but have rarely been studied in the same individuals. To examine all these factors, children, adolescents, and adults completed a gambling task with or without social rewards, played Cyberball (in which they experienced social exclusion), and then repeated the same gambling task to examine differences in reward-seeking and risk-avoidance behavior from round 1 to round 2. The aims of this study were as follows:

Aim 1: To replicate and extend behavioral findings of increased reward seeking in adolescents compared to children and adults. All three age groups completed an initial social or non-social gambling task (the modified Iowa Gambling Task used in Cauffman et al., 2010) in which reward-seeking behavior (playing from advantageous decks) and punishment avoidance (passing on disadvantageous decks) can be measured separately. I predicted that adolescents would show increased reward seeking on both gambling tasks relative to children and adults. These results are described in chapter 2.

Aim 2: To replicate and extend behavioral findings of increased sensitivity to social ostracism in adolescents. Age-group differences in mood and state anxiety following Cyberball have been shown between adolescents and adults, but have not been investigated in younger children. I predicted that adolescents would show a larger increase in negative affect and state anxiety after being excluded in Cyberball than children and adults. These results are described in chapter 3.

Aim 3: To examine the influences of mood state, sensitivity to exclusion, and anxiety on risk and reward processing. Based on the notion that anxiety leads to hypervigilance to threat and risk avoidance, I predicted that general anxiety would correlate with punishment avoidance on both gambling tasks and that social anxiety and sensitivity to ostracism would correlate with punishment avoidance on the social gambling task. These results are described in chapter 3.

Aim 4: To examine the influence of negative affect/anxiety resulting from ostracism and interactions with age and task on *changes* in gambling behavior following ostracism. I predicted that anxiety and negative mood after ostracism would predict an increase in punishment avoidance from round 1 to round 2 of the gambling task across ages. These results are described in chapter 4.

Chapter 2: The Influence of Social Stimuli on Gambling Behavior in Children, Adolescents, and Adults

Risk and Reward Processing in Development

It is widely recognized that youth, especially adolescents, make more risky decisions than adults. Adolescence is characterized at the population level by an increase in novelty seeking and risk-taking behaviors relative to both childhood and adulthood (Arnett, 1999). In other words, risky decision-making in development is characterized by an inverted U-shaped pattern that peaks in mid-adolescence. An increase in risk-taking from childhood to adolescence can be explained in part through greater access to risky situations, such as drug use, driving, and sexual activity. However, there is evidence that maturational differences also play a role. Although adolescents are able to assess the risks of various activities as well as adults when removed from the situation, they tend to make riskier decisions in the moment. The prevailing neurobehavioral explanation for this phenomenon is a combination of an immature regulation ability compared to adults and greater drive for reward compared to younger and older individuals: the “dual systems” model (Steinberg, 2010). According to this model, cognitive control and emotion regulation systems mature in a linear fashion from childhood to adulthood while the activity of reward and incentive systems follows an inverted U-shaped curve. Behavioral and neuroimaging data tend to support this dual systems model (Steinberg, Albert, Cauffman, Banich, Graham, & Woolard, 2008) or maturational imbalance model Casey, Getz, & Galvan, 2008) over a simple lack of cognitive control in adolescents.

A substantial body of research provides support for the notion of increased responsivity of reward systems in adolescence relative to childhood and adulthood.

Reward processing is often examined through the use of incentive-based tasks that simulate gambling (Bechara, Damasio, Damasio, & Anderson, 1994; Cauffman, Shulman, Steinberg, Claus, Banich, Graham, & Woolard, 2010). In these paradigms, individuals who are able to learn the most advantageous strategies for long-term gains reap the greatest rewards. Most commonly used are variants of the Iowa Gambling Task (IGT), a task that includes two decks of cards with a long-term advantage (more money is won than lost across the task) and two decks with a long-term disadvantage (more money is lost than won). Each type of deck (advantageous and disadvantageous) also varies in frequency of punishment, whereas one yields more frequent, smaller punishments and the other yields less frequent, larger punishments. Thus, long-term advantage is crossed with frequency of punishment among the four decks. Early research using this task noted that individuals with ventromedial prefrontal cortex damage, unlike healthy subjects, were not sensitive to long-term advantage, but only to the prospect of immediate rewards (Bechara, Damasio, Damasio, & Anderson, 1994). Based on the idea that adolescents show both relative prefrontal immaturity and heightened responsivity to incentives relative to adults, subsequent research using variants of the IGT has examined developmental differences between adolescents and adults. When playing the IGT, adolescents have been shown to favor decks that yield frequent rewards to a greater extent than both younger children and adults (Cauffman et al., 2010; Smith, Xiao, & Bechara, 2012). In contrast, performance on cognitive control tasks without an affective component generally increases linearly from middle childhood to adulthood (Smith et al., 2012).

The study of risk-taking in development is complicated by several factors. One is the fact that reward processing and cognitive control interact to influence performance on these incentive-driven tasks. Many studies compare adolescents to adults, but in these cases it is difficult to determine whether an age-related decrease in risk-taking behavior results from increased sensitivity to reward or decreased cognitive control in adolescence. For this reason, it is important to include younger individuals in this area of research; because we know that regulatory skills *increase* from childhood to adolescence, greater risk-taking in adolescents versus children is more likely to result from increased reward sensitivity. Therefore, the current study includes children, adolescents, and adults to fully articulate developmental changes in incentive-based decision-making.

A second complicating factor is that risk-taking by definition involves both potential reward and potential punishment (Ernst, Romeo, & Anderson, 2009). Thus, both *reward seeking* and *risk aversion* influence behavior in tasks involving incentives, and it can be difficult to disentangle the two. An individual might choose to play more from an advantageous deck rather than a disadvantageous deck because she is seeking the reward, she wants to avoid losing, or both. To look at reward seeking and risk aversion separately in development, the authors of one study modified the IGT so that individuals made play or pass decisions for a given deck on each trial rather than selecting one of the decks themselves. Reward seeking was defined by play decisions on advantageous decks, and risk aversion was defined by pass decisions on disadvantageous decks. In individuals ages 10-30, the authors found that risk aversion increased linearly with age, while reward seeking peaked in late adolescence (Cauffman et al., 2010). These results mirror other data suggesting that impulsivity declines linearly with age, while reward and sensation seeking follow an inverted U-shaped curve (Romer, 2011) that peaks in adolescence.

Patterns of Learning in Gambling Tasks

A third factor that complicates gambling tasks is that performance reflects one's ability to learn (implicitly or explicitly) about deck characteristics in addition to reward seeking and risk aversion. Learning is especially relevant in developmental studies, because data suggest that children and adolescents respond more to the frequency of wins and losses among decks than to their long-term advantage (van Duijvvenvoorde, Jansen, Bredman, & Huizenga, 2012). One recent study found that less than one third of eight- to nine-year-olds consistently preferred advantageous decks in a modified IGT; another third consistently preferred one or both low-frequency loss decks; and another third showed illogical or no clear pattern of choices (Carlson, Zayas, & Guthormenson, 2009). In another study including children and adolescents age seven to fifteen, sensitivity to long-term advantage increased with age, but only when punishment was presented infrequently. When punishment was frequent, even adolescents did not learn which decks were advantageous in the long-term (Crone et al., 2005). These results indicate that frequency of loss may interfere with both children's and adolescents' ability to learn about long-term advantage in gambling tasks. In other words, younger individuals pay more attention to *how often* they win or lose, neglecting to notice the *amount* they win or lose. Despite previous findings (Cauffman et al., 2010) that risk aversion is lower in youth than in adults, children and adolescents might be *more* risk averse than adults when loss frequency is taken into account.

Social Influences on Reward Seeking

In the standard IGT, upon which much of the literature on adolescent risk and reward processing is based, the goal is straightforward: to win as much money or as many points as possible. Yet in real life, the rewards people seek are often social in nature; for most adolescents, peer approval is incredibly important (Brown & Larson, 2009). A growing body of evidence indicates that social factors influence both adolescents' cognitive control and their risk and reward processing. Even simple social stimuli with no obvious personal relevance, such as emotional faces of strangers, appear to differentially distract adolescents relative to younger children and adults. For example, in paradigms using emotional face Go/No-go tasks, adolescents make more commission errors for No-go happy versus fear trials and have slower reaction times to Go fear versus happy trials than both adults and children (Hare et al., 2008; Somerville, Hare, & Casey, 2011). Assuming that happy faces are appetitive and fear faces are aversive, these results suggest that adolescents have more difficulty inhibiting their prepotent responses to approach an appetitive social stimulus and avoid an aversive social stimulus than other age groups. Another study utilized standard and emotional face versions of the flanker task. The face flanker task required subjects to identify the emotional expression (fear or happy) of a central face, which was flanked by either congruent or incongruent facial expressions. Adolescents responded more slowly than adults when happy faces were flanked by incongruent fear faces, but not when fear faces were flanked by happy faces, and nor during a standard letter flanker task (Grose-Fifer, Rodrigues, Hoover, & Zottoli, 2013). In this case, adolescents may have been less able to regulate their response to an aversive stimulus than adults, although they were not hindered by appetitive stimuli.

The discrepant findings for happy faces between the two studies—hindering performance in the Go/No-Go task but not the Flanker task--highlight the fact that the effects of a given stimulus depend on the context in which it is presented. In a more complicated task such as the IGT, the focus of the current study, the presence of emotional faces may influence behavior in more complex ways. Given that research thus far suggests emotional faces may be more salient to adolescents than adults (Hare et al., 2009; Grose-Fifer et al., 2013), we hypothesized that these social stimuli would impair adolescents' learning about long-term outcomes, but would have less effect on performance for adults. Based on previous findings that children respond mostly to frequency of punishment in gambling tasks (Carlson et al., 2009; Crone et al., 2005), we predicted that children would play less based on long-term outcomes than other age groups regardless of social stimuli.

To our knowledge, the influence of emotional faces on risk and reward processing, as opposed to cognitive control, has not yet been examined. However, the presence of peers has been shown to increase adolescents' tendency to make risky decisions. Gardner & Steinberg (2005) found that peer presence in a simulated driving task increased risk-taking in adolescents disproportionately compared to children and adults. Human and animal work suggests that, due to biological changes in adolescence (e.g., puberty, heightened activity of limbic brain regions) the presence of peers could both increase motivation to seek rewards and decrease aversion to punishment (Spear, 2000). In other words, peer presence may increase approach behaviors and decrease avoidance behaviors in contexts where potential risks and rewards must be weighed. Steinberg (2008) points out that most real-world risk-taking in adolescence takes place in groups, and the unique salience of peers to adolescents—perhaps due to a preoccupation with peer evaluation--could explain this phenomenon. Multiple studies show that adolescents can reason adequately about the consequences of risky behaviors in the abstract (Steinberg, 2008), but peer evaluation might add an emotional salience to otherwise straightforward situations, tipping motivation from avoidance to approach behaviors.

Alternatively, one could consider increased risk-taking in the presence of peers as a mechanism of avoiding the punishment of social disapproval rather than seeking the reward of social acceptance. Diagnoses of social phobia rise dramatically in adolescence (Beesdo et al., 2009), and social fears such as doing something in front of others and public speaking are prevalent among this age group (Essau, Conradt, & Peterman, 1999). Thus, we might expect social situations to increase adolescents' avoidance behaviors under certain circumstances. Given the known importance of peer approval and social standing in adolescence (Brown & Larson, 2009), it is important to consider social context in models of adolescent risk-taking behavior. The current study examines the effects of social stimuli on both reward seeking and punishment avoidance in adolescents and in younger and older individuals.

Current Study

The aim of this study was to examine the influence of social stimuli (happy and angry faces) on behavior during a gambling task in children, adolescents, and adults. Based on previous studies using standard gambling tasks, we predicted that 1) children and adolescents would be more sensitive to frequency of loss than long-term advantage and 2) sensitivity to long-term advantage would increase with age. We also predicted that emotional faces--happy faces for wins and angry faces for losses--would increase participants' sensitivity to frequency of loss and decrease sensitivity to long-term advantage. Finally, we hypothesized that these effects would be heightened in adolescents, who may be more motivated to see happy faces (positive social stimuli), and avoid angry faces (negative social stimuli), regardless of the number of points they win or lose.

Method

Participants

Participants (n=157) were recruited from a database maintained by the Institute of Child Development, and flyers posted around campus. Fifty (50) children ages 8-9 years (25 female, *M* age = 8.75), 58 adolescents ages 12-14 years (31 female, *M* age = 13.18) and 49 undergraduates ages 18-23 years (28 female, *M* age = 19.45) were included in the study. One male child was later excluded because he chose "play" on every trial of the gambling task. The three age groups did not differ in sex ratio ($X^{(1)} = .370$, $p = .831$), though adolescent and adult groups included slightly more females than males. Participants were excluded for any history of severe psychiatric illness or developmental disorder, including bipolar disorder, schizophrenia, personality disorders, conduct disorder, autism, Down Syndrome, epilepsy, and severe medical complications, or if they were currently taking psychoactive medication. This study was reviewed and approved by the Social and Behavioral Sciences Institutional Review Board at the University of Minnesota. Adult participants and a parent of child and adolescent participants gave informed consent. Both verbal and written assent were obtained from child and adolescent participants. Participants were compensated at the rate of $10 per hour or two extra credit points per hour (for some undergraduates). Parents of children and adolescents were compensated $10 for travel expenses.

Procedure

Participants came to the university for a single 90-minute session in which they completed a gambling task and several other tasks and questionnaires as part of a larger study on risk/reward processing and social development. Within each age group, approximately half of participants were randomly assigned to a social gambling task (25 children, 27 adolescents, 25 adults) and half were assigned to a standard (non-social) gambling task (24 children, 31 adolescents, 24 adults). The social and non-social groups did not differ on age, sex ratio, or for adolescents, pubertal development (see Table 2.1 for participant demographics). Pubertal development was measured through the self-report Physical Development Scale (Petersen, Crocket, Richards, & Meyer, 1988).

Table 2.1. Demographic Characteristics by Age Group and Gambling Task Condition

	Age M(SD)	*Sex Ratio M/F*	*PDS Average Score M(SD)*
Children			
Non-Social	8.9(0.6)	13/11	---
Social	8.6(1.6)	11/14	---
Adolescents			
Non-Social	13.1(0.5)	10/12	2.6(0.6)
Social	13.2(0.6)	12/14	2.7(0.7)
Adults			
Non-Social	20.1(1.6)	10/14	---
Social	19.7(1.6)	11/14	---

Note: PDS = Physical Development Scale (Puberty). Pubertal development was not measured in children or adults.

Modified Iowa Gambling Task. Both the social and non-social gambling paradigms were based on the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), which was designed to mimic real-world decision-making under conditions of uncertainty. In this task, a participant is presented with four decks of cards, each of which contains a net reward or punishment (the addition or subtraction of points). Two of the decks lead to net reward over the course of the task, while the other two lead to net loss, or punishment. In addition, two of the decks administer frequent punishment (70%) and two administer frequent reward (70%) (see Table 2.2).

Following the protocol of Cauffman et al. (2010), the tasks in the current study were modified so that decisions motivated by punishment avoidance and reward seeking could be measured separately. First, rather than letting participants select a deck to play from on each trial, the computer selected a deck on each trial (Deck A, B, C, or D). The participant was shown which deck the card was drawn from and could then choose to either 1) reveal the card and receive a reward or punishment (play), or 2) pass, in which case they did not see what information the card contained. Participants pressed “1” on a keyboard to play and “2” to pass and were given 4 seconds to make their decision. Also different from the standard version, each card displayed only the net outcome instead of gain and loss separately (e.g., +20 points rather than +30 points, - 10 points). This helped to ensure that working memory load did not become too high for the youngest participants and that participants used actual reward or punishment values to make subsequent decisions. Each card also displayed the words “You won!” or “You lost!” along with a black up or down arrow. The bottom of the outcome screen also displayed the participants’ cumulative number of points earned. Participants were given 2000 points to start, and the total points could not fall below 0. The task included 180 trials in 3 blocks and lasted approximately 15 minutes.

Participants were instructed to try to win as many points as they could during the task. As an incentive, they were told they would be given a $5 bonus if they earned enough points; in reality, all participants were given the bonus. Participants were told that some decks were "good" and some were "bad" and that they should try to play more from the good decks and avoid the bad decks.

Table 2.2. Deck characteristics of the social and non-social gambling tasks.

Deck A	Deck B	Deck C	Deck D
Advantageous long-term	Advantageous long-term	Disadvantageous long-term	Disadvantageous long-term
Infrequent large win (30%, +230)	Frequent small win (70%, +80)	Infrequent medium win (30%, +120)	Frequent small win (70%, +70)
Frequent small loss (70%, -70)	Infrequent medium loss (30%, -120)	Frequent small loss (70%, -80)	Infrequent large loss (30%, -230)

Social Gambling Task. In the social version of the gambling task, point values were accompanied by social rewards or punishment. For rewards, a picture of a happy face from the appeared; for punishments, a picture of a close-mouthed angry face appeared (NimStim stimulus set, Tottenham et al., 2009; see Figure 2.1). The face pictured was the same individual on every trial and was matched to the gender of the participant. The number of points won or lost was displayed in addition to faces to maintain the quantitative aspect of the task (Demurie, Roeyers, Baeyens, & Sonuga-Barke, 2012). The same verbal information was displayed as in the non-social task.

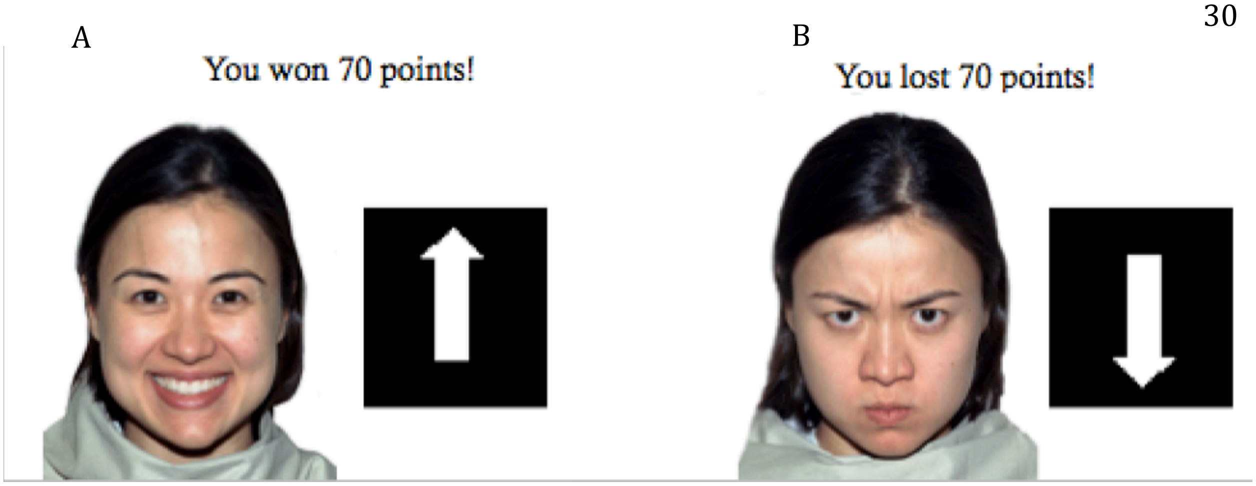

Figure 2.1. Feedback on the social (face) and non-social task (arrow) for a win outcome (A) and loss outcome (B). Faces were matched to the participant's sex.

Data Analysis

The primary variable of interest was the proportion of "play" decisions made for each deck across the task. We chose to examine this outcome variable rather than total earnings because 1) this was the primary variable examined by Cauffman et al. (2010) in the previous study reporting on this task, and 2) total earnings was more probabilistic (e.g., a subject might make one or two play decisions resulting in very bad outcomes and have low total earnings despite an overall "good" strategy on the task). Total earnings were, however, positively correlated with playing strategy (i.e., a good strategy entailed playing more often from advantageous decks and passing more often from disadvantageous decks). Reward seeking was examined along two dimensions—long-term advantage and frequency of punishment—resulting in four dependent variables of interest. Reward seeking was examined in terms of 1) proportion plays from long-term advantageous decks (A and B), and 2) proportion plays from low-frequency punishment decks (B and D). Similarly, punishment avoidance was examined in terms of 1) proportion of passes from disadvantageous decks (C and D), and 2) proportion of passes from high-frequency punishment decks (A and C). A series of repeated measures ANOVAs was used to analyze the data with age group (child, adolescent, adult) and/or context (social or non-social) as between-subjects factors. Within-subjects factors included: proportion of plays from 1) advantageous decks, 2) disadvantageous decks, 3) high-frequency loss decks and 4) low-frequency loss decks.

Results

Explicit Awareness of Deck Characteristics

After completing the gambling task, participants were asked if they could tell "which decks were good and bad." They were not required to classify each deck as good or bad, but only asked to state their general impressions. No participants accurately identified all four good and bad decks, though 33% identified one or more decks correctly and 9% identified two or more decks correctly. Participants were not significantly more likely to identify a good deck than a bad deck or vice versa. Awareness of deck characteristics did not differ by age group or task.

Overall Behavior on Gambling Task

To assess overall task effects, a 2 (long-term advantage) x 2 (frequency of punishment) ANOVA was conducted on the proportion of play choices. Despite a lack of overt awareness, a small but significant main effect of long-term advantage was observed ($F(1,153) = 36.5$, $p < .001$, $d = .233$), showing that participants played more from good decks (A and B) than from bad decks (C and D). Similarly, a significant effect of punishment frequency ($F(1,153) = 20.6$, $p < .001$, $d = .316$) confirmed that participants played more from low-frequency punishment decks (B and D) than from high-frequency punishment decks (A and C). The largest difference in play rate occurred between Deck B, from which participants played 71% of the time, and Deck C, from which participants played only 57% of the time ($t(155) = 4.6$, $p < .001$, $d = .589$). This result shows that participants responded most strongly to the *combination* of long-term advantage and punishment frequency.

Age Group Effects on Gambling Behavior

To examine age-effects on gambling behavior, a 3 (age group) x 2 (long-term advantage x frequency of punishment) ANOVA was conducted on proportion of play choices, collapsing across the social and non-social gambling task. As predicted, there was a significant age x long-term advantage interaction ($F(2,153) = 5.5$, $p = .004$). Playing more from good decks and less from bad decks across the task increased from childhood to adolescence and adulthood. Post-hoc Tukey HSD tests on the difference score between good and bad decks assessed differences between age groups, indicating that adolescents ($M = .07$, $SD = .11$) and adults ($M = .09$, $SD = .12$) tend to make decisions based on long-term advantage more often than children ($M = .01$, $SD = .12$; *ps*< .01, *d*s = .52-.67). However, adolescents and adults did not differ significantly in their consideration of long-term advantage. Follow-up one-sample t-tests indicated that children showed no evidence of considering long-term advantage ($t(48) = .723$, $p = .47$), whereas both adolescents ($t(57) = 5.2$, $p < .001$) and adults ($t(48) = 4.9$, $p < .001$) did.

Effects of Social Context on Gambling Behavior

To examine effects of social context on gambling behavior, a 3 (age group) x 2 (task: social vs. non-social) x 2 (long-term advantage) x 2 (frequency of punishment) ANOVA was conducted. There was a significant age group x task interaction (F(2, 150)

= 6.8, $p = .001$) in terms of overall proportion plays. Follow-up one-way ANOVAs examining overall proportion plays in each age group indicated that children in the social condition played less (and passed more) across all four decks than children in the non-social condition ($F(1,48) = 6.75$, $p = .012$, $d = .38$); see Figure 2.2, panel A. Adolescents assigned to the social and non-social tasks showed no differences in proportion of play decisions ($p > .8$); see Figure 2.2, panel B. Adults, however, played significantly *more* in the social task than the non-social task ($F(1,47) = 5.17$, $p < .03$, $d = .25$), particularly from bad decks (see Figure 2.2, panel C).

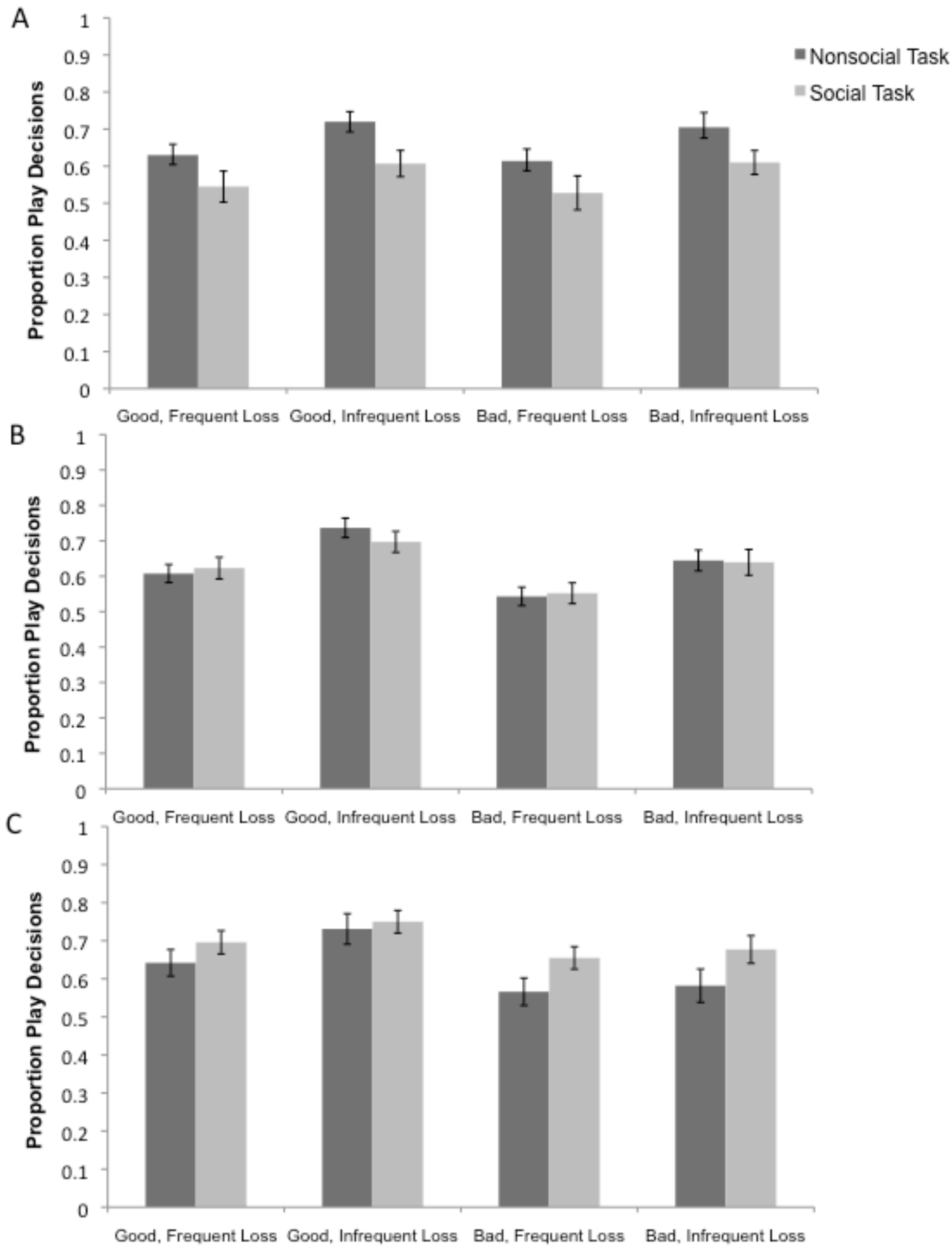

Figure 2.2. Children’s (A), Adolescents’ (B), and Adults’ (C) proportion “play” decisions.

Discussion

To our knowledge, the current study is the first to examine the influence of social stimuli on risk-taking during a gambling task. Furthermore, it is one of only a few studies to examine gambling behavior across a wide age range, including children, adolescents, and adults. We predicted that decisions based on long-term advantage in both gambling tasks would increase with age. This hypothesis was confirmed. When deciding whether to play or pass from a given deck, children only considered frequency of punishment, while adolescents and adults chose strategies based on both long-term advantage and frequency of punishment. This result is consistent with previous developmental research using similar tasks (Crone et al., 2005; van Duijvenvorde et al., 2012). Interestingly, in this variant of the IGT, decisions based on punishment frequency did not *decrease* with age. Instead, adolescents and adults combined this information with long-term advantage, demonstrating a more sophisticated strategy than children. Consistent with most data on the IGT, participants for the most part were not aware that they were using this information, but appeared to learn deck characteristics implicitly.

We also hypothesized that adding emotional faces to the gambling task would increase sensitivity to punishment frequency and decrease sensitivity to long-term advantage, particularly for adolescents, who may be more sensitive to social stimuli than other age groups. Subjects were presented with a happy face regardless of the amount they won or an angry face regardless of the amount they lost; thus, the salience of emotional faces was expected to interfere with learning about long-term advantage on the high-frequency punishment, advantageous deck and the low-frequency punishment, disadvantageous deck. We found no evidence for this pattern among adolescents;

however, young adults who completed the social gambling task did show decreased sensitivity to long-term advantage relative to their peers who completed the nonsocial task, playing more from both of the disadvantageous decks. In other words, adults who completed the social task chose to take *more* risks than those who completed the non-social task, but were not more sensitive to frequency of punishment. A potential explanation for this finding is that faces of all types were an appetitive stimulus for young adults, regardless of whether they were happy or angry. Importantly, the average age of our adult sample was under 20 years old; though past adolescence, these individuals were in “emerging adulthood” (Arnett, 2000) and most were in college, an environment in which peer relationships are often highly salient and in flux. In addition, faces in the NimStim dataset are of individuals at a similar age to our young adult sample. All these factors could contribute to young adults being drawn to social stimuli in the gambling task.

In contrast to adults, children who completed the social task showed a decreased proportion of plays from every deck relative to those who completed the non-social task. They still made decisions based on frequency of punishment, but were simply more risk averse in general. Children may have found the angry faces to be more aversive than adolescents or adults did. The face displayed on the cards was that of a young adult that could be perceived as similar to that of an authority figure, such as a parent or teacher, to children this age. Given that each deck conferred at least a 30% risk of punishment, children may have been trying to avoid the possibility of an angry face by choosing to pass more often.

Contrary to prediction, adolescents behaved nearly identically in the social and non-social conditions. This result is inconsistent with research suggesting that adolescents are more sensitive to social stimuli than children and adults (e.g., Hare et al., 2009; Grose-Fifer et al., 2013) or that adolescents take more risks in social contexts relative to other age groups (e.g., Steinberg et al., 2005). There are several potential explanations for these discrepancies. Previous research examined adolescent behavior in the context of cognitive control tasks and/or more active risky decision-making tasks such as simulated driving with or without the presence of peers. In contrast to cognitive control tasks, which are made more emotionally salient by adding emotional faces, a gambling task is already motivationally salient due to its incentive-based structure. Thus, the addition of faces, especially non-peer faces, may have little effect on the emotional salience of the task. Future research could use faces of peers or even real-life friends to increase the reward/punishment value of these social stimuli. Discrepant findings in the current study also highlight the fact that photographs of emotional faces are a very different type of social stimulus than the presence of real peers (Steinberg et al., 2005).

Contrary to previous research on basic reward processing in adolescence, the current study showed no evidence of increased reward seeking in adolescents relative to younger and older individuals in either gambling task. Our adolescent group was age 12-14, which is somewhat younger than the "peak" for risk-taking of around 14-17 observed in some other studies (e.g., Cauffman et al., 2010; Steinberg et al., 2008). This younger age group was the focus of the current study because other work has shown increased reward sensitivity in young adolescents (e.g., Galvan et al., 2006), which may be linked to puberty (Dahl, 2004). In addition, our adult group was fairly young, not far from adolescence. Indeed, Cauffman et al (2010) found that the “peak” in reward seeking in the IGT did not decline significantly until young adulthood. The current study thus provided a conservative test of whether adolescents truly differ from post-pubertal individuals in their reward sensitivity.

In contrast to the notion that adolescents are always predisposed to make riskier decisions than both children and adults, several studies support the notion that younger children and adolescents behave similarly on the IGT and other incentive-based learning tasks (Crone et al., 2005; Unger, Greulich, & Kray, 2014), or even that risky decisions decline from childhood to adolescence (Paulsen, Platt, Huettel, & Brannon, 2011). Findings that children behave similarly to adolescents while performing laboratory tasks conflict with observations that adolescents engage in riskier behavior in the real world. However, external factors such as increased freedom, opportunity, and peer pressure may account for much of the observed increase in real-life risky behavior from childhood to adolescence. If this is the case, differences between risk-taking in children and adolescents during laboratory tasks might be less pronounced than in the real world.

Though they do not take more risks in all situations, adolescents may be better equipped than children and adults to deal with situations of ambiguity and uncertainty, given the transitional nature of this developmental period. Evolutionary models suggest that adolescents should be biologically prepared to adjust their behavior in response to changing environmental demands (Crone and Dahl, 2012). Because participants in the current study were not told the characteristics of the decks, the task involved a high level of ambiguity. Importantly, the goal to win as many points as possible was the same in both the social and non-social conditions. If adolescents were more comfortable with ambiguity than children and adults, this could account for the unexpected finding that adolescents' behavior was *not* altered in the social context, while that of children and adults was. Adolescents may have been better able to stay focused on their goal despite the distraction of emotional faces. Had we instead manipulated the goal to be more social (such as winning peer approval), we might expect changes in adolescent behavior.

This last point illuminates the importance of considering what is meant by a "social context." Being in the physical presence of one's friends is quite different than encountering photographs of strangers' faces, yet both involve a social element. Going forward, researchers must think beyond social versus non-social and consider the nuances of what a social manipulation does in the context of a specific task and developmental period. For example, performing a task in the presence of a peer might have such strong effects on adolescent behavior because peer presence *changes the goal* to impressing or winning approval from that peer.

Limitations and Future Directions

This study is among the first to examine the influence of emotional faces on behavior during a gambling task. The use of a novel task involves some limitations. We chose to use a between-subjects design due to concerns about the social task bleeding into performance on the non-social task in a within-subjects design. However, the fact that different participants completed the social and non-social tasks does limit our interpretation of the data. Although groups were randomly assigned and matched for age and sex, it is possible that other unmeasured variables were different between groups. In addition, we chose to use a modified version of the IGT in which reward seeking and punishment avoidance were measured separately, but this meant that participants did not select a deck on each trial, as in the standard IGT. This version may make it more difficult for participants to learn which decks are advantageous and disadvantageous, so that behavior is a more pure measure of emotion-based aspects of decision-making rather than intelligence/learning ability (Cauffman et al., 2010). This alteration means our results are not directly comparable to more widely used versions of the IGT.

Some limitations of this research suggest interesting ideas for future directions. We used standardized NimStim faces, but, as discussed above, presenting faces of peers or even friends might make the task more emotionally salient and influence behavior in different ways. Additionally, including a continuous age range would help to capture developmental changes in risk and reward-sensitivity that may have been missed with temporally dichotomous age groups. Using emotional faces to change the goal of the task rather than using such stimuli as distractors would be an especially valuable direction for future research, based on heightened sensitivity to both incentives and social information in adolescence. Finally, examining the role of sex differences (which we were underpowered to analyze) and individual differences, such as social anxiety, on risk and reward sensitivity in a social context would aid the interpretation of age group effects.

Conclusion

Overall, results of this study support the notion that the ability to learn about long-term advantage in a gambling task increases with age. The addition of emotional faces to a gambling task had different effects in children, adolescents, and adults; adolescents behaved the same in both tasks, children took fewer risks across all decks in the social context, and adults took more risks. In contrast to findings from cognitive control tasks, our results suggest that emotional faces in the context of a gambling task are more salient to children and young adults than to adolescents. These findings highlight the importance of including both younger and older individuals in adolescent-focused research and suggest that increased risk-taking and sensitivity to social stimuli in early adolescence are not universal.

Chapter 3: Influences of Anxiety and Mood on Risk and Reward Decision-Making from Childhood to Adulthood

Introduction

Internalizing problems are characterized by the excessive experience of inwardly directed negative emotions such as sorrow, guilt, fear, and worry (Waxler, Dougan, & Slattery, 2000). Severe internalizing symptoms associated with mood and anxiety disorders are linked to problems with many aspects of daily functioning, including interpersonal interactions and emotion regulation (Waxler et al., 2000). Recent research also suggests links between these disorders and alterations in risk and reward-related decision-making in both adults (Smoski, Lynch, Rosenthal, Cheavens, Chapman, & Krishnan, year) and children (Forbes, Shaw, & Dahl, 2007). Many of the decisions in our daily lives involve weighing risks and rewards, particularly in the social realm. For example, a social interaction might entail the punishment of rejection or the rewards of acknowledgement and belonging. Thus, any variations in how we think about risks and rewards, whether due to disposition or mental health problems, may profoundly impact and shape our lives. Individual differences in children are likely to be especially influential, as the decisions children make will determine the experiences that shape them as they develop into adults. The aim of the current study was to examine influences of individual differences in anxiety and social anxiety on such decision-making in children, adolescents, and adults, and to determine whether such individual differences are more relevant when making decisions involving social feedback.

Anxiety, Depression, and Reward Processing

Anxiety disorders are characterized by hypervigilance to threat cues (Bar-Haim, Lamy, Pegamin, Bakermans-Kranenburg, & IJzendoorn, 2007) and avoidance of threatening stimuli (Gray, 1991). Gray (1991) described anxiety as an imbalance in the fight or flight system that subserves approach or avoidance behaviors, such that motivation is biased towards flight/avoidance. In laboratory tasks such as the dot-probe, patients with anxiety disorder show greater attentional biases towards threatening cues than healthy individuals (Bar-Haim et al., 2007). Heightened physiological and behavioral responses in patients with anxiety disorders have also been found with *ambiguously* threatening cues. Intriguingly, following fear conditioning, individuals with generalized anxiety disorder showed similar responses compared to healthy individuals to a clear "safe" cue, and to a cue indicating electric shock, but they showed heightened fear-potentiated startle and self-reported risk ratings in response to cues that *resembled* the shock cue, indicating overgeneralization of fear conditioning (Lissek, Kaczkurkin, Rabin, Geraci, Pine, & Grillon, 2014). In addition to physiological and behavioral evidence of vigilance for ambiguous or unlikely threat, heightened neural processing of threat has been found in anxiety disorders under circumstances in which identifying the negative valence of threatening cues was irrelevant to the task, but not when such cues were task-relevant (Straube, Kolassa, Glauer, Mentzel, & Miltner, 2004). In another study, high-trait-anxious subjects showed increased processing in error-monitoring regions compared to low-trait-anxious subjects during a decision-making task in a low error-rate condition, but not during a high error-rate condition (Paulus, Feinstein, Simmons, & Stein, 2004). As a whole, these findings could reflect increased reactivity to and/or a failure to engage regulatory mechanisms to ramp down affective responses to ambiguous, improbable, and/or task-irrelevant threatening stimuli, resulting in hypervigilance to *potential* threat. In contrast, cues that are obviously threatening and/or task-relevant should elicit high levels of processing in both anxious and healthy populations.

Affective decision-making tasks such as the Iowa Gambling Task (IGT) involve uncertainty about reward or punishment outcomes. Given hypervigilance during ambiguously threatening situations in anxiety disorders, it is not surprising that anxious individuals have been shown to behave differently than non-anxious individuals during the IGT (e.g., Miu, Heilman, & Houser, 2008). The IGT involves four decks of cards that vary in their long-term outcomes and frequency of punishment; for example, deck A is advantageous long-term, but includes high-frequency punishment. Deck B is advantageous with low-frequency punishment, deck C is disadvantageous with high-frequency punishment, and deck D is disadvantageous with low-frequency punishment. Subjects choose which deck to play on each trial, gradually learning which decks are "better bets." Most healthy adult subjects learn to play more from long-term advantageous decks during the task, but children tend to learn predominantly about the frequency of loss dimension, playing more from low-frequency loss, but not necessarily long-term advantageous, decks (Crone et al., 2007). Research suggests that subjects learn which decks are more or less advantageous through "somatic markers" (Damasio, Everitt, & Bishop, 1996), anticipatory visceral signals occurring below conscious awareness that increase over the course of the task when disadvantageous decks are played, thus directing behavior away from disadvantageous decks. Somatic markers can be measured through skin conductance and other autonomic responses during the period between deck selection and reward or punishment outcome. Importantly, in the IGT, no deck doles out reward or punishment 100% of the time; thus, each trial involves the potential for punishment. Several studies show that behavioral, physiological, and neural responses in the IGT correlate with anxiety. For example, Miu, Heilman, & Houser (2008) found that highly anxious subjects made fewer advantageous decisions than low-anxious subjects during the IGT, and also showed increased anticipatory skin-conductance and cardiac responses to *advantageous* decisions. These results suggest that anxious individuals may anticipate punishment even after making safer decisions, in line with the notion that these individuals anticipate threat in situations involving low probability of punishment. This hypervigilance may impair their ability to learn which decks are optimal. In other decision-making tasks, both anxiety disorders and higher trait neuroticism have been linked to increased risk aversion (Lauriola & Levin, 2001; Maner et al., 2007). Furthermore, concordant with the notion that anxious individuals have difficulty with emotion regulation (Cisler, Olatunji, Feldner, & Forsyth, 2010), cognitive reappraisal of negative emotions has been shown to improve performance in the IGT and reduce risk aversion in another decision-making task in healthy subjects (Heilman et al., 2010). These studies suggest links between anxiety, risk aversion, and less advantageous decision-making under conditions of uncertainty.

Although anxiety disorders are common in childhood and adolescence (Bernstein, Borchardt, & Perwien, 1996), and the IGT has been used to study risk-taking in adolescence (Cauffman et al., 2010), links between anxiety and performance on gambling tasks such as the IGT prior to adulthood have rarely been examined. One study that evaluated performance on an IGT-like decision-making task in anxious pre-adolescent boys found no concurrent differences in reward processing between healthy controls and those with anxiety disorders; however, boys who rarely chose the high-probability, large reward option were more likely to develop anxiety and depressive disorders one year later (Forbes, Shaw, & Dahl, 2007). Studies using other incentive-based decision-making tasks have also found evidence for perturbations in reward processing in anxious adolescents. One study found that, in contrast to controls, anxious adolescents did not show improved performance as a result of incentives, which suggests that the possibility of loss hindered their performance (Jazbec, McClure, Hardin, Pine, & Ernst, 2005). Other research examining adolescents identified as behaviorally inhibited in infancy, who are at heightened risk for developing anxiety disorders, has found differences between these individuals and controls at the neural level during incentive based-tasks. One study found *increased* activation in reward-related brain regions relative to controls, which was specific to conditions under which reward was contingent to behavior (Bar-Haim et al., 2009; Guyer et al., 2006). In adults, however, anxiety tends to be correlated with risk avoidance at the behavioral level (Mayer et al., 2007; Miu et al., 2008). Although heightened reward-related brain activity does not necessarily predict behavioral risk-taking, these studies suggest there are links between anxiety and risk/reward processing that these links may change across development. It is important to examine further the relations between anxiety and risk/reward processing in adolescence in particular because these years are characterized by both increased risk for anxiety disorders (Beesdo et al., 2009) and increased risky decision-making (Steinberg et al., 2005).

In contrast to anxiety, several studies have examined risk and reward processing in depressed adolescents or adolescents at risk for depression. Depression and anxiety are often comborbid in youth (e.g., Brady & Kendall, 1992) and appear to share genetic influences (e.g., Franic et al., 2010). Furthermore, anxiety symptoms in childhood tend to predict depressive symptoms in adolescence (Silk, Davis, McMakin, Dahl, & Forbes, 2012). A growing body of research suggests links between depression and altered risk and reward processing in youth. Behaviorally, adolescents at familial risk for depression have shown reduced risk-taking in a laboratory decision-making task compared to controls, particularly when there was a *high* probability of reward (Rawal, Collishaw, Thapar, & Rice, 2013). In other words, while controls took more risks when they were likely to receive a reward, decision-making behavior in at-risk adolescents was not modulated by the probability of receiving a reward. This is suggestive of a reduced drive for reward in at-risk adolescents, a notion supported by neuroimaging research. Forbes, Shaw, & Dahl (2007) found that their pre-adolescent boys with depression picked a large reward, high-probability win option less often than healthy controls, suggesting less sensitivity to reward magnitude. Altered neural activation during reward processing tasks between children and adolescents at risk for depression based on family history have also been reported. For example, Gotlib et al (2010) found that girls at risk for depression show blunted activation compared to low-risk girls in reward-processing brain regions (striatum) during the anticipation and receipt of reward, but greater activation in an error-monitoring region (dorsal ACC) during loss outcomes. This finding suggests that at-risk subjects devoted more processing resources to punishments and less to rewards than low-risk subjects. Reward-related brain activity during affective decision-making has also been shown to predict later depressive symptoms in healthy adolescents, though in the opposite direction: Telzer, Fuligni, Lieberman, & Galvan (2014) found that *greater* striatal activation in response to risk on the balloon analogue risk-taking task (BART) predicted increased depressive symptoms one year later. Although striatal activation is traditionally linked to reward processing, each balloon pump on this task confers the possibility of reward or punishment; thus, elevated neural responses in youth who later developed depressive symptoms could reflect heightened anticipation of reward, punishment, or uncertainty about the outcome. In sum, most work examining the relation between depression and reward processing in youth suggests that the risk for or diagnosis of depression is linked to greater sensitivity to punishment and/or reduced sensitivity to reward, but these sensitivities may look different depending on whether clinical depression, familial risk for depression, or depressive symptoms in healthy youth are examined. Such discrepancies suggest that reward-related antecedents to depression may be different than those that present with current depression.

One of the strongest predictors of later depression in youth is anxiety (e.g., Cole, Peeke, Lachlan, Martin, Truglio, & Seroczynski, 1998). Whereas depression may be uniquely linked to reduced drive for reward, anxiety appears to be more associated with increased sensitivity to punishment in reward-processing tasks. In a study that compared the influence of anxiety symptoms and depressive symptoms in adolescents at familial risk of depression, depressive symptoms predicted reduced risk-taking at *high* reward-probabilities, while social (but not generalized) anxiety predicted reduced risk-taking at *low* reward probabilities (i.e., high loss probabilities) (Rawal, Riglin, Ng-Knight, Collishaw, Thapar, & Rice, 2014), reflecting increased sensitivity to punishment and/or low tolerance of uncertainty in socially anxious youth. The link between anxiety and increased sensitivity to punishment could be due to more rapid acquisition of somatic markers in response to cues signaling high probability of aversive stimuli (Smoski, Lynch, Rosenthal, Cheavens, Chapman, & Krishnan, 2008). In development, this hypervigilance to potential punishment could be a pathway to anxiety disorder, which could in turn lead to blunted reward processing and depression in the later teenage years (Silk et al., 2012).

Social Influences on Reward Processing

One source of threat to which adolescents appear especially sensitive is social threat (Haddad, Lissek, Pine, & Lau, 2011; Silk et al., 2012). Evidence for this sensitivity is found both in the laboratory and in real-life behaviors. During social fear conditioning, healthy adolescents show less discrimination of fear and safety cues than adults, rating safety cues as more threatening than adults (Lau et al., 2011); this finding parallels that of hypervigilance to ambiguous threat in anxiety disorders (Lissek et al., 2014). There is also evidence that sensitivity to social threat increases from childhood to adolescence: fears about negative social evaluation have been found to increase during this transition, even as non-social fears decrease (Westenberg, Gullone, Bokherst, Heyne, & King, 2007). It is thought that a central purpose of adolescence is to transition from family-oriented to peer-oriented behavior (Nelson, Leibenluft, McClure, & Pine, 2005); thus, a heightened sensitivity to social punishment, such as peer rejection (and reward, such as peer acceptance) is likely to be adaptive for most adolescents, faciliating the learning required to make this social transition. However, this sensitivity could become maladaptive in the case of frequent peer victimization from which there is no clear "escape"—no way to modify one's behavior to avoid punishment—resulting in social anxiety. Indeed, relational victimization by peers has been shown to predict the development of social phobia in adolescents (Storch, Masia-Warner, Crisp, & Klein, 2005).

Given that anxiety appears to be linked to risk aversion in adults (Maner et al., 2012), one might expect that adolescents who develop social anxiety as a result of peer victimization might be predisposed to avoid social risks to a greater extent than those who do not develop social anxiety. A tendency to avoid all risks, even as their peers engage in more risky behavior, might increase an adolescent's risk of developing social anxiety, as well as maintain the disorder through continued avoidance of social interactions (Lorian & Grisham, 2010). However, research also shows heightened activation in brain regions associated with reward processing during affective decision-making tasks in behaviorally inhbited (Bar-Haim et al., 2009) and socially anxious adolescents (Guyer et al., 2012) compared to controls. Based on these findings, one might predict *increased* reward-seeking in anxious youth, particularly those who show symptoms of social anxiety. There is reason to believe that links between reactions to social punishment and risk-taking behavior might be different in adolescence than in other age groups due to the importance of social experiences and heightened propensity for exploration and risk taking (Steinberg et al., 2005) during this period. Thus, the current study examines the role of social context, generalized anxiety, and social anxiety on reward-related behavior in adolescents compared to younger and older individuals.

Current Study

It is often difficult to disentangle reward seeking from risk aversion on affective decision-making tasks. For example, risk aversion cannot be measured directly on the standard IGT since individuals must play (i.e., take a risk) on each trial. Thus, playing more from advantageous than disadvantageous decks could indicate reward-seeking behavior, risk-avoiding behavior, or a combination. Mixed results have been found regarding the relation between internalizing and decision-making on gambling tasks. Although some research suggests links between internalizing symptoms and less optimal decision-making performance (Forbes et al., 2007; Miu et al., 2008), other research suggests anxious or depressed individuals performed *better* than controls on the IGT because they were better at avoiding risky decks (Mueller, Nguyen, Ray, & Borkovec, 2010; Smoski et al., 2008). For the current study, we used a modified version of the IGT, based on a task designed by Cauffman and colleagues (2010) to examine risk aversion separately from reward seeking. In this version, subjects could choose to play a pre-determined deck or pass on each trial. Thus, instead of choosing which deck to play, subjects chose whether to take a risk or avoid a risk. Accordingly, in this task, our variables of interest were not overall earnings, but the extent to which subjects chose to play or pass on the various deck types.

The aims of the current study were 1) to examine the extent to which generalized anxiety predicts risky and risk-averse decision-making in school-age children, adolescents, and adults, 2) to examine the extent to which social anxiety and sensitivity to social ostracism predict such decision-making in the presence of social stimuli, and 3) to explore potential developmental differences in relations between social context, generalized anxiety, social anxiety, and risk/reward processing. To investigate these aims, we created a social version of Cauffman et al.'s modified IGT that included emotional faces as outcomes in addition to monetary rewards and punishments. We hypothesized that 1) more anxious adults would show a greater tendency to pass instead of play, indicating higher risk avoidance, regardless of social context; and 2) that subjects who were specifically more socially anxious and more sensitive to ostracism would show the same pattern of behavior primarily in a social context. Given evidence that behaviorally inhibited adolescents show increased reward processing in similar incentive-based tasks (Bar-Haim et al., 2009; Guyer et al., 2006), we hypothesized that adolescents would show the opposite pattern of relations between anxiety and affective decision-making, such that anxiety would be linked to *increased* reward-seeking (i.e., playing more from advantageous decks). For all age groups, we also predicted that anxiety would predict greater avoidance of frequent-loss decks, and would interfere with learning which decks conferred a long-term advantage, such that anxious subjects would show a reduced preference to play from advantageous vs disadvantageous decks.

Method

Participants

Participants (n=157) were recruited from a Participant Pool at the University of Minnesota, the Psychology Department Website, and flyers posted around campus. Fifty (50) children ages 8-9 years (25 female, *M* age = 8.75), 58 adolescents ages 12-14 years (31 female, *M* age = 13.18) and 49 undergraduates ages 18-23 years (28 female, *M* age = 19.45) were included in the study. One male child was later excluded because he chose "play" on every trial of the gambling task. The three age groups did not differ in sex ratio

($X^{(1)}$ = .370, p = .831), though adolescent and adult groups included slightly more females than males. Participants were excluded for any history of severe psychiatric illness or developmental disorder, including bipolar disorder, schizophrenia, personality disorders, conduct disorder, autism, Down Syndrome, epilepsy, and severe medical complications, or if they were currently taking psychoactive medication. This study was reviewed and approved by the Social and Behavioral Sciences Institutional Review Board at the University of Minnesota. Adult participants and a parent of child and adolescent participants gave informed consent. Both verbal and written assent were obtained from child and adolescent participants. Participants were compensated at the rate of $10 per hour or two extra credit points per hour (for some undergraduates). Parents of children and adolescents were compensated $10 for travel expenses.

Procedure

Participants came to the University for a single 90-minute session in which they completed two rounds of a gambling task, a peer social ostracism paradigm, and several other tasks and questionnaires as part of a study on risk/reward processing and emotional sensitivity to social exclusion. Within each age group, approximately half of participants were randomly assigned to a social gambling task (25 children, 27 adolescents, 25 adults) and half were assigned to a standard (non-social) gambling task (24 children, 31 adolescents, 24 adults). The groups were matched for age and sex ratio. Participants were debriefed at the end of the session.

Modified Iowa Gambling Task. Both the social and non-social gambling paradigms were based on the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), which was designed to mimic real-world affective decision-making under conditions of uncertainty. As described in Table 2.2, participants were presented with four decks of cards, each of which contained a net reward or punishment (the addition or subtraction of points). Two of the decks led to net reward over the course of the task, while the other two led to net loss, or punishment. In addition, two of the decks administered frequent punishment (70%) and two administered frequent reward (70%). Following the protocol of Cauffman et al. (2010), the tasks in the current study were modified so that decisions motivated by punishment avoidance and reward seeking could be measured separately.

The tasks used in this study differed from the standard Iowa Gambling Task in two important ways. First, instead of the participants selecting which deck to play from, the computer selected a deck on each trial (Deck A, B, C, or D). The participant was shown which deck the card was drawn from and could then choose to either reveal the card and receive a reward or punishment, or pass, in which case they did not see what information the card contained. Participants pressed “1” on a keyboard to play and “2” to pass and were given 4 seconds to make their decision. Also different from the standard version, each card played displayed only the net outcome instead of gain and loss separately (e.g., +20 points rather than +30 points, - 10 points). This helped to ensure that working memory load did not become too high for the youngest participants and that participants used actual reward or punishment values to make subsequent decisions. Each card also displayed the words “You won!” or “You lost!” along with an up or down arrow. The bottom of the outcome screen also displayed the participants’ cumulative number of points earned. Participants were given 2000 points to start, and the task was designed so that total points would not go below 0. The task included 150 trials over 3 blocks and lasted approximately 15 minutes.

Participants were instructed to try to win as many points as they could during the task. As an incentive, they were told they would be given a $5 bonus if they earned enough points; in reality, all participants were given the bonus. Participants were told that some decks were “good” and some were “bad” and that they should try to play more from the good decks and avoid the bad decks.

Social Gambling Task. In the social version of the gambling task, point values were accompanied by social rewards or punishment. For rewards, a picture of a happy face from the NimStim stimulus set appeared; for punishments, a picture of a close-mouthed angry face appeared (see Figure 2.1). The face pictured was the same person on every trial and was matched to the gender of the participant. The number of points won or lost was displayed in addition to faces to maintain the quantitative aspect of the task (Demurie, Roeyers, Baeyens, & Sonuga-Barke, 2012). The same verbal information was displayed as in the non-social task.

Cyberball. Following the gambling task, participants completed the Cyberball social ostracism paradigm (Williams et al., 2000). For this task, participants were told that they would play an online ball-tossing game with two peers in different parts of the country as part of a large-scale study. To facilitate this cover story, at the beginning of the session, the experimenter asked to take the participant’s picture for the online game so that the other players could see him or her. Before the game, participants were instructed to try and imagine the interactions as if they were occurring face-to-face. After they clicked "play," there was a waiting period of a few seconds in which participants were told that the remote connection between the three people was being established.

During the game, the screen displayed a first name and picture for the two "peers" in the game, which were matched to the sex and approximate age (elementary school, teen, or college-age) of the participant (see Figure 3.1). The bottom of the screen displayed participants' own first name and picture; for those who declined to have their picture included, a generic avatar was displayed. Participants indicated with a mouse which peer they wished to throw to. For the first 25 throws (inclusion), each player threw the ball back to the participant half of the time. For the last 25 throws (exclusion), the other players threw only to each other, excluding the participant.

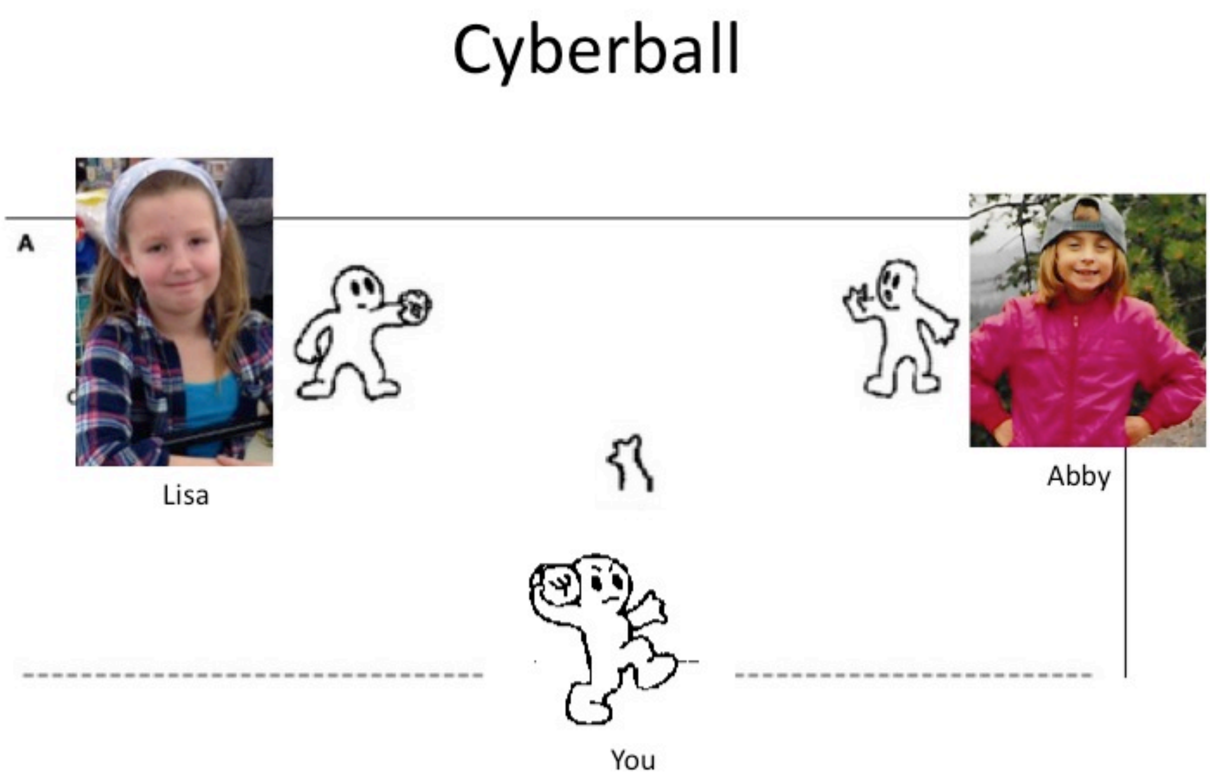

Figure 3.1. Cyberball Task Display for an 8-10 year-old female participant who chose not to have her picture displayed. "Peers" at the top of the screen were matched to the age and sex of the participant.

Cyberball Manipulation Check. At the end of the session, participants were asked if they thought they were playing against real people during Cyberball. Answers were coded into "yes," "no," or "maybe" categories.

Questionnaires

Ratings of Mood and Game Evaluation. At the beginning of the session, between the gambling task and Cyberball, and after Cyberball, participants rated how good/bad, happy/sad, friendly/unfriendly, tense/relaxed, sure/unsure, frustrated/content, and energetic/tired they felt on a scale of 1-7, for a total of three mood ratings throughout the session. Energetic/tired was a filler question, and children had difficulty understanding the terms "tense" and "content." Thus, the scales of good/bad, happy/sad, friendly/unfriendly, and sure/unsure were used to calculate negative affect at each time point.

After the first gambling task and after Cyberball, subjects were additionally asked to rate on a scale of 1-7 how much they liked/disliked the game, felt in control/lacked control during the game, felt good/bad about themselves during the game, found the game exciting/boring, found the game hard/easy, and would want to play again. After Cyberball, they rated the extent to which they would want to play again with 1) the same players and 2) different players. This questionnaire was used as a filler following the gambling task, but questions addressing control and feeling good about oneself were included in subsequent analyses as measures of two of the "four human needs"—control and self-esteem--found to be altered following ostracism (Williams et al., 2000). In addition, ratings of desire to play again with the same and different players following Cyberball were analyzed to examine the effectiveness of the ostracism manipulation, as well as participants' generalization of this negative social experience.

State-Trait Anxiety Scale. (Spielberger et al., 1983). Participants reported their trait anxiety at the beginning of the session and state anxiety at two time points—the beginning of the session and following Cyberball--using the state/trait anxiety inventory (STAI-S). This questionnaire consists of 20 statements (e.g., "I feel calm") or ("I feel nervous and restless") rated for the extent to which they describe the participant on a scale of 1 to 4. For state anxiety (STAI-S), participants rated how they felt "right now, at this moment." For trait anxiety, (STAI-T), participants rated how they generally felt most of the time. Adults completed the standard version of the STAI, while adolescents and children completed the child version (STAI-C.)

Social Anxiety Scale (La Greca & Lopez, 1998). Participants completed the Social Anxiety Scale for Adolescents, a 20-item questionnaire evaluating Fear of Negative Evaluation, Social Avoidance and Distress in General, and Social Avoidance Specific to New Situations or Unfamiliar Peers. All age groups completed the same form, but some items were re-worded to enhance comprehension for children (e.g., "peers" changed to "kids"). Total score was used as the dependent variable.

Results

Data Analysis

We first characterized overall behavior on the gambling task, levels of anxiety, and emotional reactions to Cyberball by age group using ANOVAs. We focused our analyses on the following variables from the gambling task: overall proportion of plays (higher = more risky decision-making), proportion of plays from infrequent-loss vs frequent-loss decks (higher = greater sensitivity to frequency of punishment), and proportion of plays from advantageous vs disadvantageous decks (higher = greater sensitivity to long-term advantage). For anxiety, mood, and sensitivity to social exclusion, we focused on the following self-rated variables: state anxiety, trait anxiety, social anxiety, baseline mood, and change in mood/state anxiety after playing Cyberball. Parent ratings of anxiety were highly skewed, so we did not include these in our models. To examine relations between anxiety, sensitivity to ostracism, and decision-making, we performed hierarchical linear regressions, entering first card task (social or non-social), then age group, then anxiety/mood variables, and finally interaction terms (age x anxiety or task x anxiety). We performed these regressions on the following dependent variables: 1) overall proportion plays, 2) proportion infrequent-loss vs frequent-loss plays to examine short-term reward seeking/risk aversion and 3) proportion advantageous vs disadvantageous plays to examine long-term reward seeking/risk aversion. In cases where age group significantly predicted decision-making behavior *and* we had a priori predictions regarding links between anxiety and decision-making in a specific age group, we followed up with raw correlations examining effects of anxiety and mood on decision-making in children, adolescents, and adults separately.

Behavior on the Gambling Task

As discussed in chapter 1, all age groups played more from infrequent-loss than from frequent-loss decks (main effect of loss frequency; $F(1,153) = 20.6$, $p < .001$), and adolescents and adults, but not children, played more from advantageous than from disadvantageous decks (age group x long-term advantage interaction; $F(2,153) = 5.5$, $p = .004$.). In a multivariate ANOVA examining effects of age and card task condition, there were no main effects of card task condition (social or non-social), though there was a significant interaction between age and card task condition on overall proportion of plays ($F(2,147) = 6.55$, $p = .002$): there were no age group differences on the nonsocial task, but on the social task, children played least (i.e., passed most), adolescents played an intermediate amount, and adults played most. There were no significant task or age x task effects on playing from high vs low-frequency loss decks or playing from advantageous vs disadvantageous decks.

Reactions to Cyberball

We next examined subjects' reactions to Cyberball, focusing on whether they believed the other players were real, the extent to which negative affect increased after being excluded, and the subjects' interest in playing again with the same players vs different players. A sub-group of 10 adolescents who completed an inclusion-only version of Cyberball were excluded from all analyses involving reactions to Cyberball.

Cyberball Manipulation Check. Our attempts to make Cyberball believable were moderately successful. After all tasks were completed but before the debriefing, subjects were asked "Did you think the other players were real people?" Verbal responses were coded as yes, maybe, or no. Among children, 86% said they thought the peers were real people, 4% expressed some doubts, and 10% thought they were not real. Among adolescents, the corresponding response codes were 39.5% yes, 37.5% maybe, and 23% no. Among adults, 47% responded yes, 28.5% were coded maybe, and 24.5% were coded no.

Age Group Differences in Anxiety and Mood

Self-reports of anxiety and mood ratings in each age group are described in Table 3.1. Age-group differences were examined for each outcome variable (negative affect at baseline and after Cyberball, trait anxiety, state anxiety at baseline and after Cyberball, and social anxiety) using one-way ANOVAs with three age groups. Age groups did not differ in levels of negative affect at baseline or after Cyberball. However, there was a main effect of age group for *change* in negative affect from baseline to post-Cyberball ($F(2,142) = 5.8$, $p = .004$); children ($M = .04$, $SD = .87$) showed a smaller increase in negative affect than adolescents ($M = .73$, $SD = 1.15$) or adults ($M = .53$, $SD = .99$). Adolescents and adults did not significantly differ from each other in their change score. In a separate one-way ANOVA, we tested whether change in state anxiety from baseline to post-Cyberball differed between age groups, and found no significant differences. In addition, age group differences were found for all anxiety self-ratings: baseline state anxiety ($F(2,143) = 3.6$, $p < .03$), post-Cyberball state anxiety ($F(2,142) = 7.0$, $p = .001$), trait anxiety ($F(2,142) = 12.8$, $p < .001$), and social anxiety ($F(2,143) = 3.8$, $p < .03$). In each instance, adults reported significantly higher levels of anxiety than children and adolescents as indicated by post-hoc Tukey tests.

Changes in Mood. We examined changes in mood (self-rating of negative affect) following ostracism in a 2 x 3 repeated measures ANOVA with time (baseline and following Cyberball) as a within-subject variable, and age group (child, adolescent, adult) as a between-subjects variable. There was a main effect of time ($F(1,139) = 27.2$, $p < .001$) in that subjects reported an increase in negative affect following Cyberball. In addition, there was a significant age x time interaction ($F(2,139) = 6.1$, $p = .003$). Follow-up t-tests revealed that adolescents and adults reported an increase in negative affect following Cyberball, while children did not. Thus adolescents and adults reported stronger emotional reactions to the task despite being less likely to believe that they had been ostracized by real people.

Another 2 x 3 repeated measures ANOVA with State Anxiety as the outcome variable revealed a main effect of time ($F(1,142) = 9.56$, $p = .002$): subjects reported more general anxiety after being excluded in Cyberball. There was also a main effect of age group ($F(2, 142) = 6.2$, $p = .002$), which resulted from adults reporting greater anxiety than children and adolescents at both time points (see Table 3.1).

A final 2 x 3 repeated measures ANOVA analyzed subjects' ratings of the extent to which they would consider playing the game again with 1) the same players and 2) different players. There was a main effect of same vs different ($F(1,143) = 63.4$, $p < .001$): subjects said they would be more willing to play again with different players than with the same players. There was also a main effect of age ($F(2,143) = 10.35$, $p < .001$). Post-hoc Tukey tests (STATS) indicated that children expressed more desire to play again with both same ($M = 3.3$, $SD = 1.8$) and different players ($M = 5.1$, $SD = 1.8$) than adolescents (same: $M = 2.9$, $SD = 1.3$; different: $M = 4.3$, $SD = 1.6$) or adults (same: $M = 2.9$, $SD = 1.5$; different: $M = 3.8$, $SD = 1.6$). Overall, self-reported changes in mood and anxiety, and desire to play again with the same vs different players, suggest that the Cyberball task was effective in inducing negative emotions associated with ostracism.

Table 3.1. Anxiety and Mood Scores by Age Group: Mean, Standard Deviation, Range

	Trait Anxiety	Social Anxiety	Baseline Negative Affect	Negative Affect Post-CB	Baseline State Anxiety	State Anxiety Post-CB
Children *M (SD; Range*)	33.2 (5.8; 22-46)	38.9 (11.7; 19-65)	2.3 (0.8; 1-4)	2.4 (1.0; 1-4.25)	28.8 (3.2; 20-37)	29.2 (5.0; 20-41)
Adolescents *M (SD; Range)*	31.5 (6.5; 20-52)	38.9 (11.0; 19-74)	2.0 (1.1; 1-5.5)	2.8 (1.3; 1-6)	29.9 (3.9; 21-44)	31.0 (3.5; 22-40)
Adults *M (SD; Range)*	39.2* (10.7; 22-63)	44.3* (12.5; 18-79)	2.3 (1.0; 1-4.25)	2.8 (1.2; 1-5.75)	31.8* (8.8; 20-54)	34.3* (10.2; 20-55)

Note: CB = Cyberball. * Indicates significant difference from other age groups ($p < .05$).

Correlations among Anxiety Measures

Because age groups differed in levels of anxiety, we examined correlations among state anxiety, trait anxiety, and social anxiety in these three groups separately (children, adolescents, and adults). As predicted, all three measures were positively correlated in children, adolescents and adults, though positive correlations between state anxiety and social anxiety were significant only in adults (see Table 3.2).

Table 3.2. Correlations among Anxiety Measures

	Social Anxiety	State Anxiety	Trait Anxiety
Adults (n = 49)			
Social Anxiety	--	.40**	.66**
State Anxiety		--	.68**
Trait Anxiety			--
Adolescents (n = 58)			
Social Anxiety	--	.16	.61**
State Anxiety		--	.32*
Trait Anxiety			--
Children (n = 49)			
Social Anxiety	--	.24	.65**
State Anxiety		--	.28*
Trait Anxiety			--

***$p < .05$ **$p < .01$**

Correlations between Anxiety and Mood

We then examined relations between the three anxiety scales and both baseline negative affect and *change* in negative affect in response to social ostracism. Because adults differed from other age groups in anxiety and children differed from other age groups in negative affect change, we examined correlations separately in each age group. As shown in Table 3.3, both state and trait anxiety were significantly related to baseline negative affect in all age groups. Social anxiety predicted baseline negative affect in children and adults, but not in adolescents. Instead, in adolescents only, social anxiety predicted increased negative affect following ostracism.

Table 3.3. Correlations between anxiety and negative affect

	Social Anxiety	State Anxiety	Trait Anxiety
Adults (n = 49)			
Baseline NA	.56**	.68**	.68**
Cyberball NA	.23	.57**	.49**
Change in NA	-.27	.01	-.07
Adolescents (n=48)			
Baseline NA	.16	.33*	.33**
Cyberball NA	.47**	.32*	.31*
Change in NA	.34*	.05	.11
Children (n=49)			
Baseline NA	.51**	.34*	.39**
Cyberball NA	.22	.32*	.25
Change in NA	-.21	.06	-.07

***p < .05 **p < .01**

Predictions from Anxiety to Decision-Making

We examined the extent to which anxiety ratings (state anxiety, trait anxiety, and social anxiety) predicted total proportion plays, infrequent-loss vs frequent-loss plays, and advantageous vs disadvantageous plays using nine hierarchical linear regression models. In step 1 we entered task (social or non-social). In step 2 we entered dummy codes for age group using adults as the reference group. In step 3 we entered the anxiety measure (state, trait, or social), which was mean-centered. In step 4 we entered interaction terms for age x anxiety. We performed separate models testing the interactions of social anxiety with task in step 4; steps 1-3 were the same in these models.

For the model with social anxiety and social anxiety x age group predicting total proportion plays, none of the steps predicted significant variance in the final model; the only significant predictor was child vs other age group in step 2 (see table 3.4), indicating that children played less than other age groups. For the model with social anxiety x task predicting total proportion plays in step 4, this interaction was a marginal predictor, indicating that participants reporting higher levels of social anxiety who completed the social task played more than those who completed the nonsocial task, while participants with low social anxiety showed the opposite pattern (see Figure 3.2). In the models with social anxiety and social anxiety x task or social anxiety x age predicting advantageous vs disadvantageous plays, only the variable child vs other entered in step 2 was a significant predictor ($B = -.076$, $\beta = -.29$, $t = -3.2$, $p = .002$), indicating that children distinguished advantageous and disadvantageous decks less than adolescents and adults, as reported previously. In the models with social anxiety and its interactions with age or task predicting low-frequency-loss vs high-frequency-loss plays, none of the variables entered predicted significant variance in the outcome measure. In sum, social anxiety did not significantly predict gambling task behavior, though it did interact with task to predict slightly different patterns of overall risk-taking in the social vs non-social task. This marginal interaction was contrary to our hypothesis; we predicted that more socially anxious individuals would have more aversion to angry faces, and therefore play less on the social relative to nonsocial task.

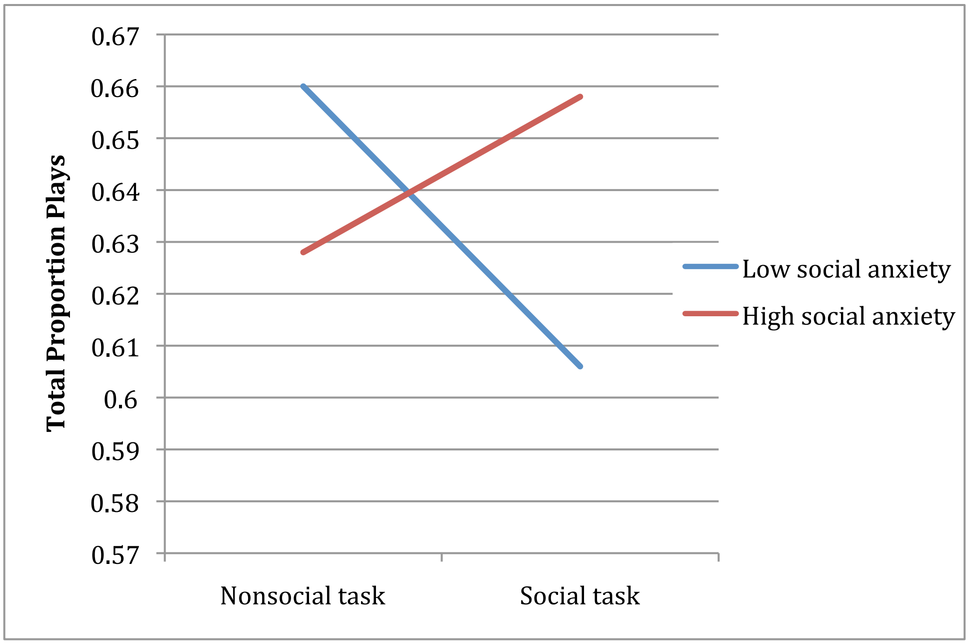

Figure 3.2. Interaction between social anxiety and task predicting total proportion plays.

Table 3.4. Summary of hierarchical linear regression analysis for social anxiety x task predicting total proportion plays

Variable	B	*SE* B	β	*ΔR²*
Block 1				.004
Task	-.013	.018	-.060	
Block 2				.029
Task	-.014	.018	-.062	
Child vs Other	-.045	.022	-.192*	
Adolescent vs Other	-.033	.021	-.147	
Block 3				.007
Task	-.017	.018	-.076	
Child vs Other	.041	.023	-.172^	
Adolescent vs Other	-.029	.022	-.129	
Social Anxiety	.001	.001	.084	
Block 4				.019^
Task	-.015	.018	-.069	
Child vs Other	-.041	.022	-.173^	
Adolescent vs Other	.026	.022	-.112	
Social Anxiety	-.001	.001	-.096	
Social Anxiety x Task	.003	.002	.229^	

Note: Social anxiety was centered at its mean.

^ $p < .1$ * $p < .05$ ** $p < .01$

In the models with state and trait anxiety and their interactions with age predicting total plays and advantageous vs disadvantageous plays, only child vs other age predicting significant variance in the model. However, in the models with these variables predicting low vs high-frequency loss plays, both state and trait anxiety and their interactions with age significantly predicted this outcome (see tables 3.5 and 3.6). Both state anxiety and trait anxiety predicted tendency to play more from frequent-loss decks than from infrequent-loss decks. Although this finding is opposite to prediction, frequent-loss decks did yield lower *magnitude* losses (see Table 2.2); thus, it appears that anxious subjects found high magnitude losses to be particularly aversive and chose to avoid those decks. The significant interactions with age group in step 4 were due to more anxious adults showing the tendency to differentiate high and low-frequency loss decks to a lesser extent than less anxious adults (see Figure 3.3); in contrast, children and adolescents who were more anxious tended to favor the low-frequency loss decks more. State and trait anxiety showed nearly identical main effects and interaction effects on this outcome. When we entered both anxiety measures in the same model, neither significantly predicted low vs high-frequency loss over and above the other due to high collinearity.

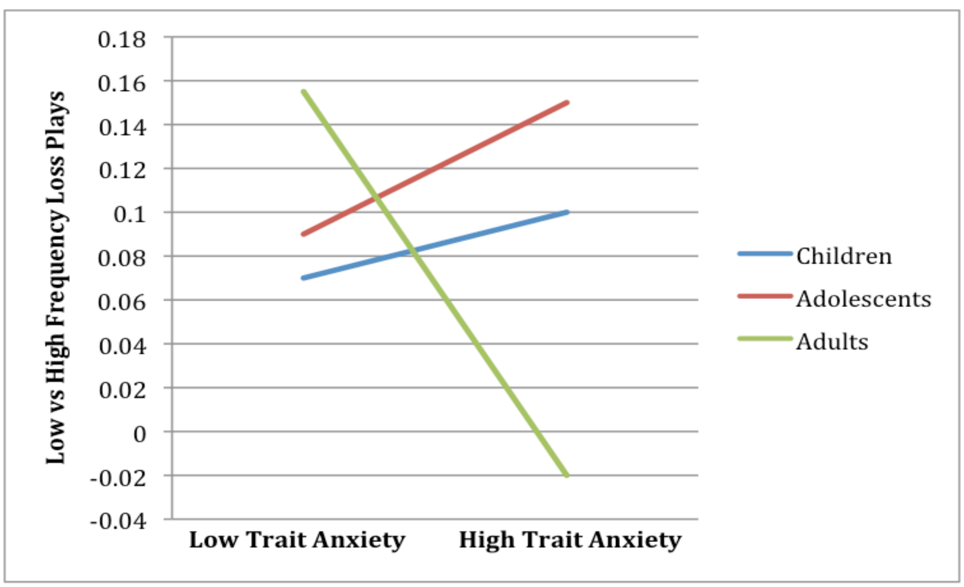

Figure 3.3. Trait anxiety and age interaction predicts low- vs high-frequency-loss plays.

Table 3.5. Summary of hierarchical linear regression analysis for trait anxiety and trait anxiety x age predicting low-frequency loss vs high-frequency loss plays

Variable	B	*SE* B	Β	*ΔR²*
Block 1				.004
Task	-.028	.033	-.067	
Block 2				.011
Task	-.026	.033	-.063	
Child vs Other	.037	.042	.082	
Adolescent vs Other	.053	.040	.124	
Block 3				.037*
Task	-.021	.033	-.052	
Child vs Other	.004	.044	.010	
Adolescent vs Other	.014	.043	.032	
Trait Anxiety	-.005	.002	-.21*	
Block 4				.045*
Task	-.024	.032	-.058	
Child vs Other	-.007	.043	-.016	
Adolescent vs Other	.014	.043	.032	
Trait Anxiety	-.010	.003	-.40**	
Trait Anxiety x Child	.011	.006	.167^	
Trait Anxiety x Adolescent	.012	.005	.238*	

Note: Trait anxiety was centered at its mean. ^ $p < .1$ * $p < .05$ ** $p < .01$

Table 3.6. Summary of hierarchical linear regression analysis for state anxiety and state anxiety x age predicting low-frequency loss vs high-frequency loss plays (blocks 3 and 4 only)

Variable	B	*SE* B	Β	*ΔR²*
Block 3				.04*
Task	-.020	.033	-.049	
Child vs Other	.013	.042	.030	
Adolescent vs Other	.039	.040	.091	
State Anxiety	-.007	.003	-.204*	
Block 4				.07**
Task	-.026	.032	-.063	
Child vs Other	.024	.043	.054	
Adolescent vs Other	.033	.039	.078	
State Anxiety	-.013	.003	-.364**	
State Anxiety x Child	.019	.010	.17^	
State Anxiety x Adolescent	.023	.007	.266**	

Note: State Anxiety was centered at its mean.

^ $p < .1$ * $p < .05$ ** $p < .01$

Because playing from 1) advantageous vs disadvantageous decks in both gambling tasks and 2) overall proportion plays in the social task were both strongly influenced by age group (children made fewer plays), potentially preventing later entered variables from predicting significant variance in the outcome, we examined raw correlations between anxiety and these variables in each age group separately. Combining social and non-social tasks, social anxiety (r(58) = .26, p < .06) and trait anxiety (r(58)

= .24, p < .08) among adolescents showed marginal positive correlations with overall proportion plays (see Figure 3.4 for scatterplot of social anxiety and total plays in adolescence). Thus, more anxious adolescents showed slightly *more* willingness to take risks than less anxious adolescents in this task. In contrast, correlations between all three anxiety measures and total proportion of plays for younger children and adults were close to 0 (ps > .5). No significant correlations between anxiety variables and advantageous vs disadvantageous plays were found in any age group.

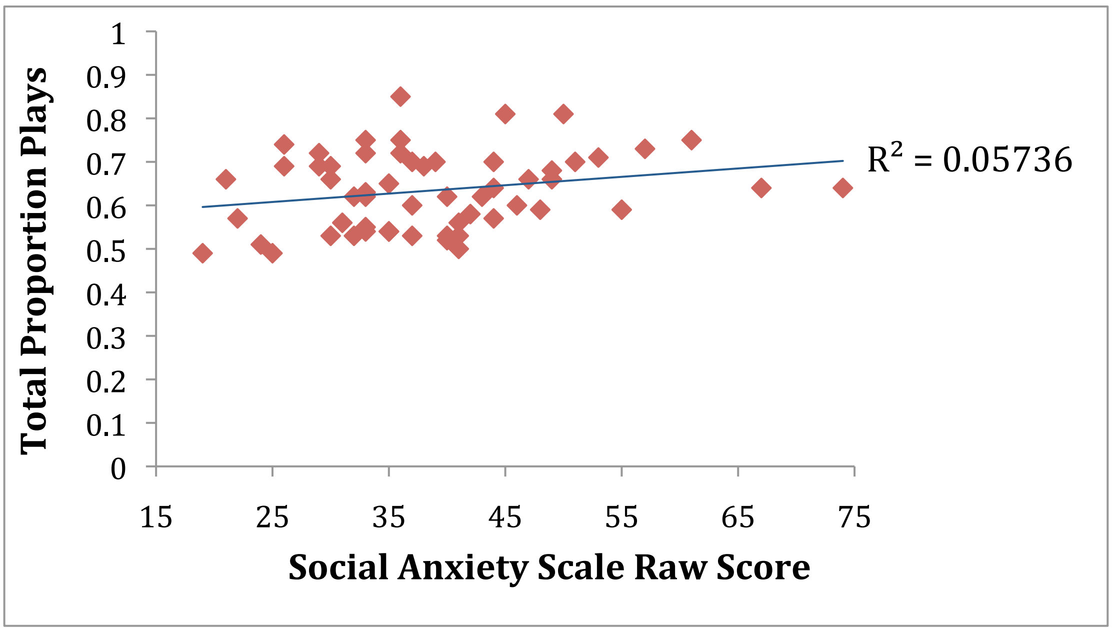

Figure 3.4. Relationship between social anxiety and total proportion plays in adolescents

Impact of Sensitivity to Ostracism on Risky Decision-Making

We examined the extent to which 1) negative affect following ostracism and 2) state anxiety following ostracism predicted the same outcome variables on the gambling task using hierarchical linear regressions controlling for baseline negative affect in step 1, and entering subsequent steps in the same sequence described above. Results showed that neither negative affect ratings nor state anxiety ratings after Cyberball predicted any outcome variables in the gambling task over and above age and baseline negative affect, nor did these variables show significant interactions with age or task.

Discussion

We predicted that more subjects with higher general anxiety in all age groups would show higher risk avoidance on both gambling tasks. We also predicted that anxious subjects would show fewer tendencies to play from advantageous vs disadvantageous deck because anxiety/hypervigilance to threat may interfere with learning about long-term outcomes (e.g., Miu et al., 2008). Neither of these predictions was supported by the data. Instead, we found that anxiety, in adults, did not predict more risk aversion in general, but did seem to be associated with avoiding decks that yielded higher magnitude losses (which were also decks that yielded infrequent losses). This same tendency to avoid large, infrequent losses has been found in adults with generalized anxiety disorder compared to controls (Mueller, Nguyen, Ray, & Borkovec, 2010). Thus, our results support the notion that adults with higher levels of anxiety may tend towards more pessimistic future-oriented thinking: i.e., they expect to receive large losses again and therefore avoid these decks. However, they were not less likely to take risks on relatively “safe” decks, reflected in the fact that there was no effect of state or trait anxiety for overall risk-taking. Due to a high degree of collinearity between social and general anxiety, we could not distinguish differential effects of state or trait anxiety on the tendency to play from high- vs low-frequency-loss decks.

In terms of task effects, we predicted that more socially anxious/sensitive to ostracism subjects would show more risk aversion (i.e., passing vs playing) primarily in a social context. Instead, we found a trend such that more socially anxious individuals across ages tended to make more risks overall if they were assigned the social gambling task and fewer risks if they were assigned the nonsocial gambling task, while less socially anxious individuals showed the opposite pattern. Possibly, this could reflect a greater reward value conferred by happy faces for more socially anxious individuals, though it is surprising that these participants did not seem to find angry faces to be more aversive. In social anxiety disorder, there is evidence for a "high-novelty-seeking, impulsive subtype," (Kashdan & Hofmann, 2008), describing socially anxious individuals who are relatively approach-oriented, disinhibited, and have greater risk for substance abuse disorders. Though we tested a healthy sample, it is possible that our more socially anxious participants showed tendencies in this direction (we did not measure general risk-taking behavior to evaluate this possibility). We remain cautious in interpreting this interaction effect given that it was opposite to our prediction and at trend level.

The data also showed trends indicating unique relationships between anxiety and risk-taking in adolescents. In adolescents, but not children or adults, trait anxiety and social anxiety trended towards predicting increased risk-taking overall. In contrast to some previous studies (Steinberg et al., 2005; Galvan et al., 2006), we did not find that adolescents as a group made more risky decisions than children or adults, only that the relations between anxiety and reward responsivity was different. This finding provides preliminary behavioral support for the notion of heightened reward sensitivity in anxious adolescents found in some brain imaging studies (Bar-Haim et al., 2009; Guyer et al., 2006). In contrast to findings in adults, increased anxiety in adolescents was not related to changes in the distribution of decks in which subject made play decisions; instead, anxiety appeared to increase the overall rate of playing instead of passing.

Intriguingly, recent behavioral findings suggest that frequent peer victimization over time, which has been shown to predict anxiety (Prinstein, Cheah, & Guyer, 2005), is also associated with increased risky decision-making in adolescence (Telzer et al., 2014). In addition, social anxiety has been shown to interact with acute social stress to predict more risky decision-making in adolescents (Reynolds, Schreiber, Geisel, MacPherson, Ernst, & Lejuez, 2013). Thus, an emerging literature, including the current findings, suggests that anxiety in adolescents may be linked to increased reward sensitivity and risky decision-making in certain contexts. Of course, risky decision-making in laboratory tasks with relatively low stakes does not necessarily translate to real-world behavior. However, such a link, if replicated in larger samples, could help to explain the increases in both risk-taking and internalizing problems observed in adolescence.

Our finding of a positive relation between anxiety and risky decision-making unique to adolescence also parallels human and animal work on fear learning in development. Compared to younger and older individuals, adolescents show decreased expression of contextual fear (Pattwell, Lee, & Casey, 2013). Adolescence is the developmental period in which individuals separate from the parents and explore new environments; thus, a certain degree of "fearlessness" may be adaptive (Spear, 2000). Although fear in adults is linked to avoidance of the context in which an aversive stimulus was experienced, this tendency in adolescents might inhibit the exploration necessary to transition to adulthood. Similarly, anxiety might be expressed differently in adolescence, leading to exploration/approach behaviors towards potential threat rather than avoidance. This intriguing notion needs replication, however, given that the correlation between social anxiety and risk-taking in adolescents was only at trend level.

Some important limitations of this work must be noted. First, all links between anxiety, sensitivity to ostracism, and decision-making were correlational; thus, any given causal direction between variables cannot be assumed. For example, although we favor the interpretation that trait aspects of anxiety influence decision-making, a third variable we did not assess, such as outside life stressors, could have influenced both subjects' ratings of their anxiety and their decision-making. In addition, due to the between-subjects design, we had low power to detect significant correlations specific to the social or to the non-social gambling task (i.e., we were unable to thoroughly investigate task-based differences in relations between anxiety/mood and gambling behavior). Finally, our assessments of anxiety and mood were based on self-report, which are not always accurate or correlated with physiological measures of mood and anxiety. Future work should investigate relations between these variables using more comprehensive assessments of mood and anxiety, ideally at multiple levels of analysis. Factors such as skin conductance responses, heart-rate, and cortisol levels can yield information about mood, anxiety, and stress that is more objective than self-reports.

In sum, these results suggest important developmental differences in the relations between anxiety, emotional reactions to ostracism, and affective decision-making. These data replicate work suggesting that anxiety is associated with avoidance of high-magnitude punishment in adults, and suggest intriguing new directions for conceptualizing relations between anxiety and risky decision-making in adolescence. In particular, future work should investigate the intriguing notion that anxiety and/or social stress specifically among adolescents leads to *increased* risk-taking. The current findings highlight the importance of considering both development and the role of social feedback when examining relations among these variables.

Chapter 4: Developmental Changes in Effects of Peer Ostracism on Decision-Making

Introduction

During adolescence, individuals begin to separate from their parents and form deeper relationships with peers. This shift in one's social network is one of the defining features of adolescence, and behaviors that facilitate this shift are likely to be adaptive over time (Nelson, Leibenluft, McClure, & Pine, 2005). One notable change in behavior during adolescence is increased risk-taking relative to childhood and adulthood (Steinberg et al., 2005; Galvan et al, 2006). Although increased risky decision-making among adolescents occurs in many domains, this tendency, both in the laboratory and in real life, is especially pronounced when teens are in the presence of peers, indicating a strong susceptibility to peer influence (Steinberg, 2008).

Numerous studies using laboratory-based risky decision-making tasks have shown that peer presence increases risk-taking in adolescents disproportionately compared to children and adults (e.g., Gardner & Steinberg, 2005). Evidence for increased susceptibility to peer influence during adolescence has also been found in the brain: adolescents, but not children or adults, were found to activate reward-processing regions (ventral striatum) more strongly in the presence of peers (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011). The prevalent explanation for this phenomenon is that peer presence increases adolescents' motivation to seek rewards and decreases their aversion to punishment (e.g., Spear, 2001). Interestingly, adolescents can reason quite adequately about the consequences of risky behavior in the abstract (Steinberg, 2008), but the presence of incentives, including peer approval, might override this reasoning to result in increased risk-taking.

Increased susceptibility to peer influence among adolescents might also be explained by the unique salience of peers to this age group. As individuals move from childhood to adolescence, they become more sensitive to social information, particularly as it relates to peers (Blakemore & Mills, 2014). Both positive and negative peer-related experiences may become more important in adolescence; for example, peer acceptance may become more rewarding and peer rejection more punishing. In general, this increased salience is adaptive, facilitating exploration and transition to new social networks (Nelson et al., 2005), but it may also result in a preoccupation with peer evaluation. Though most research examining peers and adolescent risk-taking has focused on the drive to gain peer approval, motivation to avoid the social punishment of peer disapproval may be just as influential, if not more so. Supporting this notion, recent cross-sectional research has documented that feelings of embarrassment while anticipating and experiencing peer evaluation increases during the transition to adolescence before declining again in adulthood (Somerville, Jones, Ruberry, Dyke, Glover, & Casey, 2013). Furthermore, research has shown that while children generally become more fearless as they transition to adolescence, fears about negative social evaluation actually increase during this transition (Westenberg, Gullone, Bokherst, Heyne, & King, 2007). Based on these findings, increased drive for reward in peer settings might not fully explain adolescent susceptibility to peer influence. It is easy to imagine scenarios in which adolescents make risky decisions based on peer influence in order to avoid negative peer evaluation.

Recent research also suggests that negative peer experiences increase adolescents' susceptibility to peer influence and risky decision-making. One task that is often used to elicit feelings of social rejection in the laboratory is the Cyberball game (Williams et al., 2000), in which a subject is ostracized by virtual peers during a ball-tossing game. Adolescents have been shown to experience greater negative affect and anxiety resulting from ostracism during Cyberball than adults (Sebastian et al., 2010). Furthermore, in a study that combined the Cyberball exclusion paradigm with a risky decision-making task (the Stoplight driving task), adolescents who were low in resistance to peer influence showed increased risk-taking after Cyberball (Peake et al., 2013). Importantly, subjects in this study were led to believe that the virtual peers who had just excluded them were watching them perform the task. In addition, the subject and two virtual peers had completed the driving task together before playing Cyberball. While this finding could reflect increased reward-seeking behavior following social ostracism, the presumed presence of peers complicates its interpretation, making it difficult to disentangle reward seeking from punishment avoidance. For example, adolescents low in resistance to peer influence may have increased their risky-decision making because they wanted to perform better than the peers who had just excluded them (reward-seeking) or because they were afraid the peers would make fun of their performance if they played it safe (punishment avoidance). Another study reporting that *chronic* peer conflict produces a similar increase in risky decision-making on a different task helps to clarify these findings (Telzer, Fuligni, Lieberman, Miernicki, & Galvan, 2014). In this study, adolescents who reported higher peer conflict over the past two years took more risks, even when apart from peers, suggesting that peer conflict might produce a domain-general increase in reward drive. Alternatively, adolescents who took more risks may have been more impulsive, which could also produce more conflict with peers. Furthermore, peer conflict is different than peer victimization or ostracism; in the latter scenario, the victimized individual may have less control over the peer situation. In sum, although these preliminary findings are intriguing, more work is needed to articulate the links between peer experiences and risk-taking.

Links between negative peer experiences and increased risk-taking in adolescence are somewhat surprising, given that peer ostracism produces increased anxiety (Sebastian et al., 2010), and anxiety has been linked to *reduced* risk-taking, at least in adults (e.g., Miu, Heilman, & Houser, 2008). In contrast to the view that negative peer experiences increase reward-seeking, some have hypothesized that a normative increase in social reward seeking in adolescence, when combined with negative social experiences (e.g., peer rejection), could *dampen* reward systems over time (Davey, Yucel, & Allen, 2008). According to this model, increased desire for social reward that is repeatedly frustrated leads to a gradual reduction in reward drive, so that systems that were previously overactive become underactive. Supporting this model, peer victimization is a strong predictor of adolescent depression (Barchia & Bussey, 2010; Hawker & Boulton, 2000), and depression has been associated with lower levels of reward-seeking and reward-related neural activation in response to appetitive stimuli in youth (Forbes et al., 2006; Monk et al., 2008). These two models are not mutually exclusive, however: for example, acute peer victimization, such as that experienced in the Cyberball task, might increase reward drive, while chronic victimization that occurs over several years might reduce reward drive over time. In addition, depression tends to develop later in adolescence, when individuals are closer to adulthood and adolescent-specific heightened reward drive may be returning to baseline.

The current study focuses on the first question, whether acute peer ostracism increases reward-seeking behavior in adolescents. Our goals were 1) to replicate and extend this finding using a different risky decision-making task (a modified Iowa Gambling Task); 2) to determine whether the presence of social feedback in the decision-making task moderates this link; and 3) examine potential links between acute peer ostracism and reward-seeking in younger (children) and older individuals (young adults). This last goal is particularly important, as previous studies examining this link have only included adolescents. Other age groups must be examined to determine whether this link is unique to adolescence. Regarding reactions to ostracism, we predicted that adolescents would experience greater ostracism-related negative affect and anxiety relative to adults (replicating Sebastian et al., 2010) *and* relative to younger children. In other words, ostracism-related negative affect and anxiety would follow an upside-down U-shaped curve throughout development, similar to what is observed with risk-taking. Regarding links between ostracism and risk-taking, we hypothesized that 1) more negative mood following acute peer ostracism would predict more risky decision-making in adolescents, 2) this link would be more pronounced in a task with social feedback, and 3) in contrast to adolescents, adults who reacted more negatively to peer ostracism would show *decreased* risk-taking. We did not have a specific hypothesis regarding links between these factors in children, as very little is known about either reactions to acute ostracism or risky decision-making in children.

Method

Participants

Participants (n=147) were recruited from a Participant Pool at the University of Minnesota, the Psychology Department Website, and flyers posted around campus. Fifty (50) children ages 8-9 years (25 female, *M* age = 8.75), 48 adolescents ages 12-14 years (26 female, *M* age = 13.18) and 49 undergraduates ages 18-23 years (28 female, *M* age = 19.45) were included in the study. One male child was later excluded because he chose "play" on every trial of the gambling task. The three age groups did not differ in sex ratio ($X^2(1) = .370$, $p = .831$), though adolescent and adult groups included slightly more females than males. Participants were excluded for any history of severe psychiatric illness or developmental disorder, including bipolar disorder, schizophrenia, personality disorders, conduct disorder, autism, Down Syndrome, epilepsy, and severe medical complications, or if they were currently taking psychoactive medication. This study was reviewed and approved by the Social and Behavioral Sciences Institutional Review Board at the University of Minnesota. Adult participants and a parent of child and adolescent participants gave informed consent. Both verbal and written assent were obtained from child and adolescent participants. Participants were compensated at the rate of $10 per hour or two extra credit points per hour (for some undergraduates). Parents of children and adolescents were compensated $10 for travel expenses.

Procedure

Participants came to the University for a single 90-minute session in which they completed two rounds of a gambling task, a peer social ostracism paradigm, and several other tasks and questionnaires as part of a study on risk/reward processing and emotional sensitivity to social exclusion. Within each age group, approximately half of participants were randomly assigned to a social gambling task (25 children, 26 adolescents, 25 adults) and half were assigned to a standard (non-social) gambling task (24 children, 22 adolescents, 24 adults). The groups were matched for age and sex ratio. Participants were debriefed at the end of the session.

Modified Iowa Gambling Task. Both the social and non-social gambling paradigms were based on the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), which was designed to mimic real-world affective decision-making under conditions of uncertainty. As described earlier, participants were presented with four decks of cards, each of which contained a net reward or punishment (the addition or subtraction of points). Two of the decks led to net reward over the course of the task, while the other two led to net loss, or punishment. In addition, two of the decks administered frequent punishment (70%) and two administered frequent reward (70%) (see Table 2.2). Following the protocol of Cauffman et al. (2010), the tasks in the current study were modified so that decisions motivated by punishment avoidance and reward seeking could be measured separately.

The tasks used in this study differed from the standard Iowa Gambling Task in two important ways. First, instead of the participants selecting which deck to play from, the computer selected a deck on each trial (Deck A, B, C, or D). The participant was shown which deck the card was drawn from and could then choose to either reveal the card and receive a reward or punishment, or pass, in which case they did not see what information the card contained. Participants pressed "1" on a keyboard to play and "2" to pass and were given 4 seconds to make their decision. Also different from the standard version, each card played displayed only the net outcome instead of gain and loss separately (e.g., +20 points rather than +30 points, - 10 points). This helped to ensure that working memory load did not become too high for the youngest participants and that participants used actual reward or punishment values to make subsequent decisions. Each card also displayed the words "You won!" or "You lost!" along with an up or down arrow. The bottom of the outcome screen also displayed the participants' cumulative number of points earned. Participants were given 2000 points to start, and the task was designed so that total points would not go below 0. The task included 150 trials over 3 blocks and lasted approximately 15 minutes.

Participants were instructed to try to win as many points as they could during the task. As an incentive, they were told they would be given a $5 bonus if they earned enough points; in reality, all participants were given the bonus. Participants were told that some decks were "good" and some were "bad" and that they should try to play more from the good decks and avoid the bad decks. In the second round of the task, the decks were rearranged, and participants were told that the good and bad decks might be different. Thus, participants could not use their knowledge from the first round to guide their decisions on the second round.

Social Gambling Task. In the social version of the gambling task, point values were accompanied by social rewards or punishment. For rewards, a picture of a happy face from the NimStim stimulus set appeared; for punishments, a picture of a close-mouthed angry face appeared (see Figure 2.2). The face pictured was the same person on every trial and was matched to the gender of the participant. The number of points won or lost was displayed in addition to faces to maintain the quantitative aspect of the task (Demurie, Roeyers, Baeyens, & Sonuga-Barke, 2012). The same verbal information was displayed as in the non-social task.

Cyberball. Following the gambling task, participants completed the Cyberball social ostracism paradigm (Williams et al., 2000). For this task, participants were told that they would play an online ball-tossing game with two peers in different states as part of a large-scale study. To facilitate this cover story, at the beginning of the session, the experimenter asked to take the participant's picture for the online game so that the other players could see him or her. Before the game, participants were instructed to try and imagine the interactions as if they were occurring face-to-face. After they clicked "play," there was a waiting period of a few seconds in which participants were told that the remote connection between the three people was being established.

During the game, the screen displayed a first name and picture for the two "peers" in the game, which were matched to the sex and approximate age (elementary school, teen, or college-age) of the participant. The bottom of the screen displayed participants' own first name and picture; for those who declined to have their picture included, a generic avatar was displayed. Participants indicated with a mouse which peer they wished to throw to. For the first 25 throws (inclusion), each player threw the ball back to the participant half of the time. For the last 25 throws (exclusion), the other players threw only to each other, excluding the participant.

Cyberball Manipulation Check. At the end of the session, participants were asked if they thought they were playing against real people during Cyberball. Answers were coded into "yes," "no," or "maybe" categories.

Questionnaires

Ratings of Mood and Game Evaluation. At the beginning of the session, between the gambling task and Cyberball, and after Cyberball, participants rated how good/bad, happy/sad, friendly/unfriendly, and tense/relaxed, sure/unsure, frustrated/content, and energetic/tired they felt on a scale of 1-7, for a total of three mood ratings throughout the session. Energetic/tired was a filler question, and children had difficulty understanding the terms "tense" and "content." Thus, the scales of good/bad, happy/sad, friendly/unfriendly, and sure/unsure were used to calculate negative affect at each time point.

After the first gambling task and after Cyberball, subjects were additionally asked to rate on a scale of 1-7 how much they liked/disliked the game, felt in control/lacked control during the game, felt good/bad about themselves during the game, found the game exciting/boring, found the game hard/easy, and would want to play again. After Cyberball, they rated the extent to which they would want to play again with 1) the same players and 2) different players. This questionnaire was used as a filler following the gambling task, but questions addressing control and feeling good about oneself were included in subsequent analyses as measures of two of the "four human needs"—control and self-esteem--found to be altered following ostracism (Williams et al., 2000). In addition, ratings of desire to play again with the same and different players following

Cyberball were analyzed to examine the effectiveness of the ostracism manipulation, as well as participants' generalization of this negative social experience.

Anxiety Measures. Participants reported their trait anxiety at the beginning of the session and state anxiety at two time points—the beginning of the session and following Cyberball--using the state/trait anxiety inventory (STAI-S; Spielberger et al., 1983). This questionnaire consists of 20 statements (e.g., "I feel calm") or ("I feel nervous and restless") rated for the extent to which they describe the participant on a scale of 1 to 4. For state anxiety (STAI-S), participants rated how they felt "right now, at this moment." For trait anxiety, (STAI-T), participants rated how they generally felt most of the time. Adults completed the standard version of the STAI, while adolescents and children completed the child version (STAI-C.).

Pubertal Development. In addition to the above questionnaires, adolescents also completed the Physical Development Scale (Petersen, Crockett, Richards, & Boxer, 1988), which consists of five self-rated items based on Tanner pubertal staging.

Results

Data Analysis Plan

First, we characterized subject demographics within each age (child, adolescent, adult) x task condition (social, nonsocial) group and examined differences between groups using one-way ANOVAs. Then we checked that the Cyberball manipulation was effective in inducing feelings of ostracism using repeated measures ANOVAs. We then used one-way ANOVAs to examine the effects of age group on changes in mood resulting from Cyberball. Finally, we used hierarchical linear regression to examine the extent to which task condition, age group, and negative mood/anxiety resulting from ostracism predicted changes in behavior on the gambling task from round 1 to round 2.

Cyberball Manipulation Check.

Our attempts to make Cyberball believable were moderately successful. Subjects' verbal responses to "Did you think the other players were real people" (asked before the debriefing) were coded as yes, maybe, or no. Among children, 86% said they thought the peers were real people, 4% expressed some doubts, and 10% thought they were not real. Among adolescents, the corresponding response codes were 39.5% yes, 37.5% maybe, and 23% no. Among adults, 47% responded yes, 28.5% were coded maybe, and 24.5% were coded no.

Changes in Mood and Anxiety.

We examined changes in mood following ostracism in a 2 x 3 repeated measures ANOVA with time (baseline and following Cyberball) as a within-subject variable and age group (child, adolescent, adult) as a between-subjects variable. There was a main effect of time ($F(1,139) = 27.2$, $p < .001$) in that subjects reported an increase in self-ratings of negative affect following Cyberball. In addition, there was a significant age x time interaction ($F(2,139) = 6.1$, $p = .003$). Follow-up simple effects (paired samples) t-tests revealed that adolescents and adults reported an increase in negative affect following Cyberball (*p*s < .002), while children did not ($p > .7$); see Figure 4.1. Thus, adolescents and adults reported more negative emotional reactions to Cyberball despite being less likely to believe that they had been ostracized by real people. Post-hoc Tukey tests on the difference scores in negative affect (post-Cyberball – baseline) revealed that children showed significantly less change in negative affect than adolescents ($p = .004$) and adults

(p = .05). However, adolescents' and adults' change in negative affect from baseline to post-Cyberball were not significantly different from one another (p = .6).

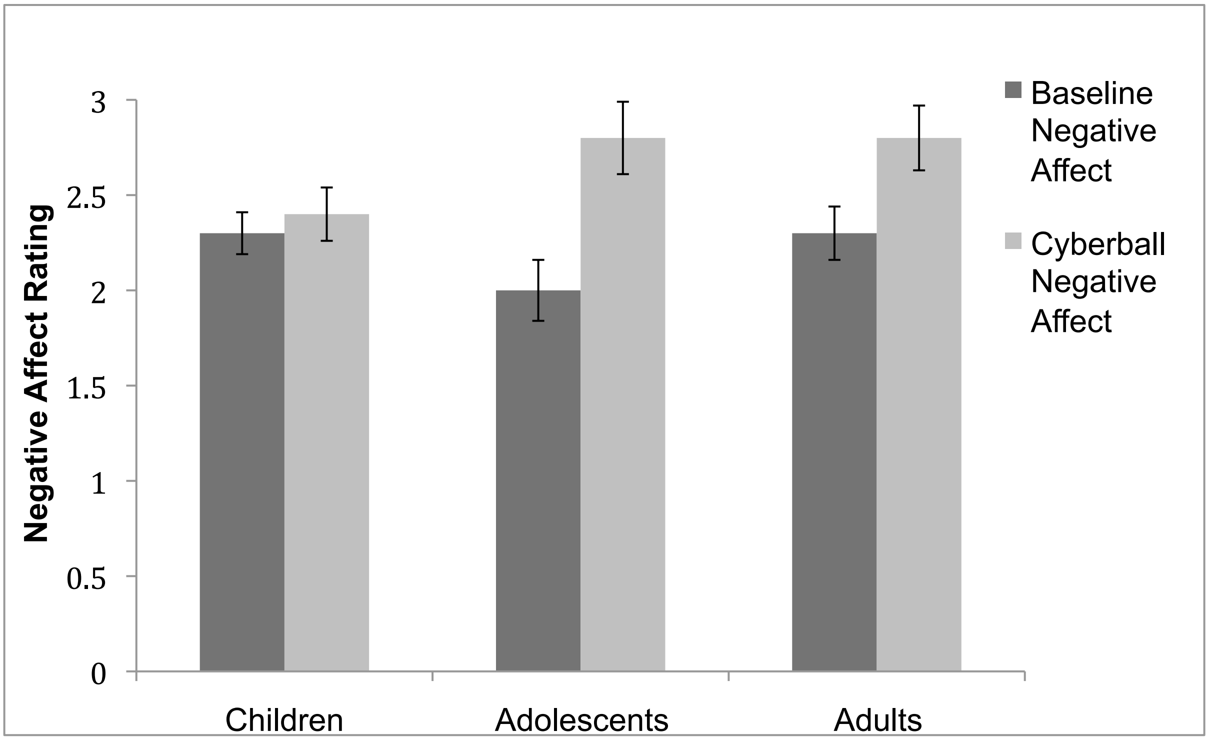

Figure 4.1. Negative affect before and after Cyberball in each age group

A 2 (time) x 3 (group) repeated measures ANOVA with State Anxiety as the outcome variable revealed a main effect of time (F(1,142) = 9.56, p = .002): regardless of age, subjects reported more state anxiety after being excluded in Cyberball. There was also a main effect of age group (F(2, 142) = 6.2, p = .002), which resulted from adults reporting greater anxiety than children and adolescents at both time points.

A final 2 x 3 repeated measures ANOVA analyzed subjects' ratings of the extent to which they would consider playing the game again with 1) the same players and 2) different players. There was a main effect of same vs different (F(1,143) = 63.4, p < .001): subjects said they would be more willing to play again with different players than with the same players. There was also a main effect of age ($F(2,143) = 10.35$, $p < .001$). Post-hoc Tukey tests indicated that children expressed more desire to play again with the same ($M = 3.3$, $SD = 1.8$, $p < .03$) and with different players ($M = 5.1$, $SD = 1.8$, $p = .001$) than adults (same: $M= 2.9$, $SD = 1.5$; different: $M = 3.8$, $SD = 1.6$), but that adolescents' responses to these questions did not significantly differ from those of children or adults (ps > .09). Overall, self-reported changes in mood and anxiety, and greater desire to play again with different than with the same players across all age groups, suggest that the Cyberball task was effective in inducing negative emotions associated with ostracism.

Because a substantial portion of adolescents and adults did not believe the Cyberball manipulation, we examined whether this affected their self-reported reactions to the task. Change in negative affect, change in state anxiety, desire to play again with the same players, and desire to play again with different players were compared between participants who believed the other players were real (coded "yes") and those who expressed doubt that they other players were real (coded as "maybe" or "no") using one-way ANOVAs. No significant difference between groups emerged, though adolescents who expressed doubts reported marginally less increase in negative affect than those who believed the other players were real ($p = .09$). Because reactions to Cyberball did not generally differ based on participants' beliefs about the other players, we included participants who expressed doubt in subsequent analyses, but controlled for belief status.

Changes in Gambling Task Behavior after Ostracism

Gambling Task Behavior. As reported previously, subjects in all age groups were sensitive to the frequency of loss among the decks prior to ostracism, playing more from low-frequency- than from high-frequency-loss decks (ADD STATS). Using a 2 (high-frequency loss and low frequency loss) x 3 (age group) mixed model ANOVA, the same main effect was found on the second round of the task, after ostracism ($F(1,140) = 15.1$, $p < .001$). On the second round, there was also a significant effect of age group ($F(2, 140) = 4.59$, $p = .012$) that was not present in the first round. Follow-up Tukey tests revealed that children played more than adolescents from both types of decks (i.e., they played more overall; $p < .01$), while adults played at an intermediate level and did not significantly differ from children or adolescents. Overall, children played 67.9% of the time on the second round (SD = 19.1%), adolescents 57.6% (SD = 17.2%), and adults 64.4% (SD = 13.6%).

Because we were interested in the extent to which negative emotions and anxiety resulting from ostracism would predict *change* in affective decision-making, we created difference scores comparing behavior from the second round of the game (post-ostracism) to the first round (baseline). Change in overall rate of playing (vs passing) was used to measure general change in risk-taking. To examine punishment avoidance more specifically, we also measured the extent to which the rate of playing from high-frequency loss and low-frequency-loss decks changed after ostracism.

Age Group Differences in Change in Gambling Task Behavior

A 2 (time: baseline and post-ostracism) x 3 (age-group) repeated measures ANOVA examining change in total proportion plays on the gambling task (collapsing across the social and non-social task) revealed no main effect of time or age group, but there was a significant time x age group interaction. Adolescents and adults decreased their proportion of plays (i.e., they passed more) after ostracism vs before, while children increased their proportion of plays. Post-hoc Tukey tests examining the difference score (round 2 – round 1) showed that children (M = .06, SD = .13) differed significantly from both adolescents (M = -.05, SD = .12) and adults (M = -.02, SD = .10), who did not differ from each other. This result parallels the main effect of age regarding overall proportion of plays in round 2 of the task.

Predictions from Ostracism Reactions to Gambling Task Behavior

Using hierarchical linear regressions, we examined the extent to which reactions to ostracism (negative affect and state anxiety) predicted 1) change from round 1 to round 2 in overall proportion plays, 2) change in high-frequency loss plays, and 3) change in low-frequency loss plays. For the regression models, in step 1 we controlled for baseline negative affect or state anxiety and the dichotomous variable describing whether subjects believed the other Cyberball players were real (yes vs no/maybe). In step 2 we entered task (social or non-social). In step 3 we entered dummy codes for age group using adults as the reference group. In step 4 we entered post-Cyberball negative affect or state anxiety, which were mean-centered. In step 5 we entered interaction terms for age x post-Cyberball negative affect or age x post-Cyberball anxiety. We performed separate models testing the interactions of post-Cyberball negative affect or anxiety with task in step 5. Raw correlations among these predictor variables are shown in Table 4.1.

Table 4.1. Raw correlations among predictor variables in regression models.

	Age	Task	CB Belief	NA Baseline	SA Baseline	NA Post-CB	SA Post-CB
Age	--						
Task	-.03	--					
CB Belief	-.29**	-.12	--				
NA Baseline	.05	.04	.11	--			
SA Baseline	.24**	.07	-.04	.47**	--		
NA Post-CB	.16^	.08	.00	.52**	.43**	--	
SA Post-CB	.30**	.06	-.10	.45**	.67**	.61**	--

Note: CB = Cyberball, NA = Negative Affect, SA = State Anxiety; ^ $p < .1$ * $p < .05$ ** $p < .01$

In the model predicting change in total playing from post-Cyberball negative affect (see Table 4.2), both control variables were significant in step 1. Individuals with higher baseline negative affect and who believed the other players were real tended to decrease their playing less in round 2. In step 2, adding task to the model did not predict significant variance in the outcome measure. In step 3, the comparison of children to adolescents and adults added significant variance to the model, and this was the only predictor that was significant in subsequent models. The main effect of age was due to children playing more on the second round and adults and adolescents playing less. In step 4, when controlling for previous factors, negative affect post-Cyberball was not a significant predictor of change in overall playing. However, in step 5, the interaction between child vs other age groups and negative affect post-Cyberball was marginally significant, though the addition of this interaction did not result in a significant change in R^2. As shown in Figure 4.2, at high levels of negative affect following ostracism, children played more (i.e., took more risks) in round 2, whereas adults and adolescents slightly decreased their playing (i.e., took fewer risks). Thus, overall tendencies for children to play more and adolescents/adults to play less in the second round were more pronounced with higher negative affect.

Table 4.2. Summary of hierarchical linear regression analysis for variables predicting change in total proportion plays

Variable	B	*SE* B	β	*ΔR²*
Block 1				.07**
Baseline NA	.025	.011	.182*	
Belief	.045	.022	.172*	
Block 2				.001
Baseline NA	.025	.012	.180*	
Belief	.046	.022	.176*	
Task	.009	.021	.035	
Block 3				.096**
Baseline NA	.020	.011	.148^	
Belief	.006	.023	.025	
Task	.010	.020	.038	
Child vs Other	.074	.026	.275**	
Adolescent vs Other	-.033	.025	-.119	
Block 4				.005
Baseline NA	.014	.013	.105	
Belief	.005	.023	.018	

Task	.009	.020	.034	
Child vs Other	.080	.027	.294**	
Adolescent vs Other	-.034	.025	-.122	
Post-CB NA	.009	.011	.082	
Block 5				.023
Baseline NA	.015	.013	.112	
Belief	.001	.024	.003	
Task	.011	.020	.045	
Child vs Other	.084	.027	.31**	
Adolescent vs Other	-.038	.025	-.138	
Post-CB NA	-.012	.016	.111	
Post-CB NA x Child	.043	.023	.195^	
Post-CB NA x Adolescent	.027	.021	.148	

Note: NA = Negative Affect; CB = Cyberball. Negative affect was centered at its mean.

^ $p < .1$ * $p < .05$ ** $p < .01$

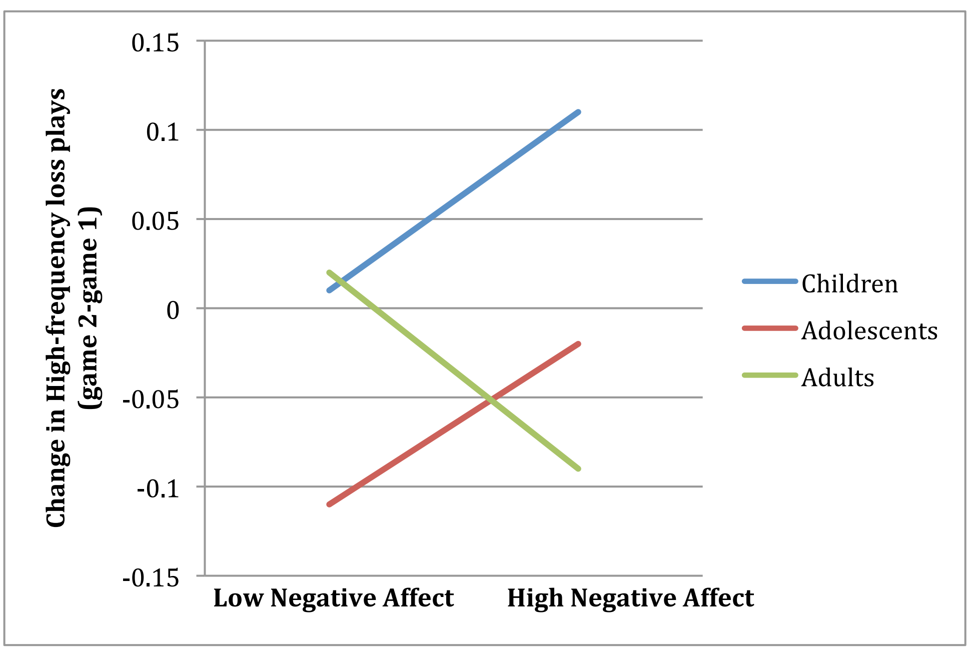

Figure 4.2. Interaction between age and negative affect after ostracism on change in high-frequency loss plays

In the model predicting change in total playing from post-Cyberball state anxiety, belief was again significant in step 1, but only child vs other age group was a significant predictor in subsequent models. Neither state anxiety nor its interaction with age added significant variance to the model.

In the model predicting change in high-frequency loss plays from post-Cyberball negative affect, steps 1-4 looked very similar to the model predicting overall proportion plays (see Table 4.3). Belief about other players was again a significant predictor in step 1, though baseline negative affect was not. Child vs other age again added significant variance to the model, indicating that children decreased their playing from high-frequency loss decks in round 2 less than other age groups. Negative affect post-Cyberball did not add significant variance to the model in step 4. However, in step 5, negative affect interacted with both “child vs other” and “adolescent vs other” to produce significant variance in the outcome variable. As shown in figure 4.3, children and adolescents who reported higher levels of negative affect after Cyberball decreased their playing from high-frequency loss decks less than those with lower levels of negative affect, while adults showed the opposite pattern.

Table 4.3. Summary of hierarchical linear regression analysis for variables predicting change in high-frequency loss plays

Variable	B	*SE* B	β	ΔR^2
Block 1				.042^
Baseline NA	.015	.016	.083	
Belief	.062	.030	.177*	
Block 2				.003
Baseline NA	.015	.016	.080	
Belief	.064	.030	.182*	
Task	.018	.029	.053	
Block 3				.05*
Baseline NA	.012	.016	.063	
Belief	.025	.033	.072	
Task	.018	.029	.053	
Child vs Other	.082	.037	.224*	
Adolescent vs Other	-.017	.036	-.046	
Block 4				.003
Baseline NA	.006	.019	.030	
Belief	.024	.033	.067	
Task	.017	.029	.050	
Child vs Other	.087	.038	.239*	
Adolescent vs Other	-.018	.036	-.049	
Post-CB NA	.009	.015	.062	
Block 5				.08**
Baseline NA	.008	.018	.045	
Belief	.010	.032	.030	
Task	.025	.028	.073	
Child vs Other	.096	.037	.262*	

Adolescent vs Other	-.030	.035	-.081
Post-CB NA	-.048	.022	-.321*
Post-CB NA x Child	.103	.032	.347**
Post-CB NA x Adol. Adolescent	.080	.029	.326**

Note: NA = Negative Affect; CB = Cyberball. Negative affect was centered at its mean.

^ $p < .1$ * $p < .05$ ** $p < .01$

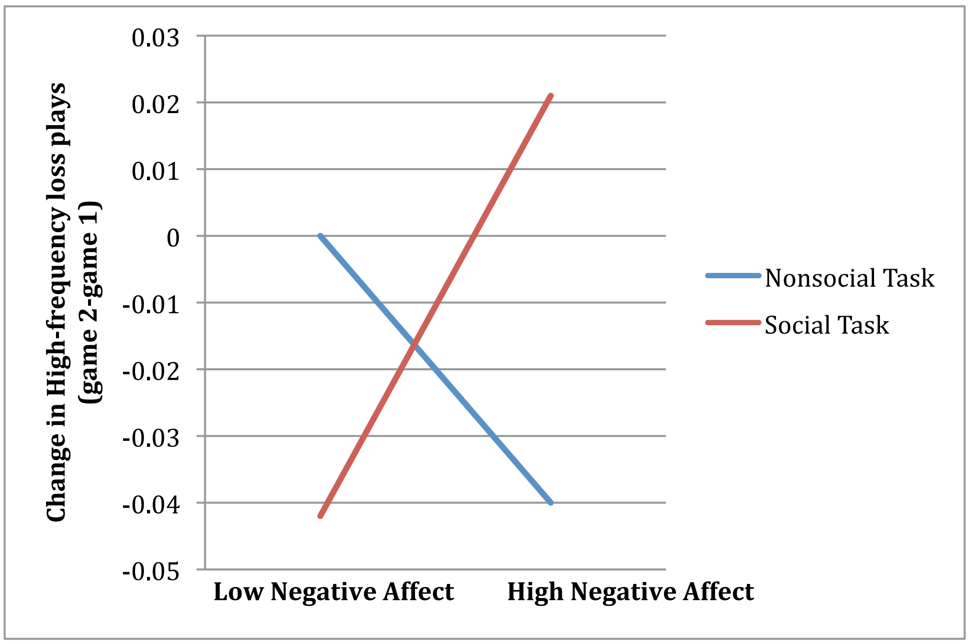

Figure 4.3. Interaction between task and negative affect after ostracism on change in high-frequency loss plays

In the model predicting change in high-frequency loss plays from post-Cyberball state anxiety, belief was again significant in steps 1 and 2, but only child vs other age group was a significant predictor in subsequent models. Neither baseline state anxiety, state anxiety after Cyberball, nor its interaction with age added significant variance to the model.

In the model predicting change in low-frequency loss plays from post-Cyberball negative affect, baseline negative affect was significant in steps 1 and 2 ($B = .03$, $\beta = .18$, $t = 2.2$), indicating that subjects with higher levels of negative affect decreased their playing from these decks less. Only child vs other age group was a marginal predictor in subsequent models, again indicating that adolescents and adults decreased playing more than children. Neither negative affect post-Cyberball nor interactions with age predicted low-frequency loss plays. In the model predicting change in low-frequency loss plays from state anxiety, no predictor variables were significant.

We then tested regression models entering task x negative affect/anxiety interactions in step 5 instead of interactions with age. For the dependent variables of change in total proportion plays and change in low-frequency loss plays, neither the task x negative affect nor the task x state anxiety interaction added significant variance to the models. However, the interaction between task and post-Cyberball negative affect was a significant predictor of change in high-frequency loss plays (see Table 4.4). As shown in Figure 4.4, individuals who completed the social task and reported high levels of negative affect after Cyberball decreased their playing from these risky decks *less* than those reporting low levels of negative affect; individuals who completed the nonsocial task showed the opposite pattern.

Table 4.4. Summary of hierarchical linear regression analysis showing task x negative affect predicts change in high-frequency loss plays (block 5 only)

Variable	B	*SE* B	β	*ΔR²*
Block 5				.035*
Baseline NA	.005	.018	.029	
Belief	.034	.033	.098	
Task	.019	.028	.055	
Child vs Other	.091	.038	.248*	
Adolescent vs Other	-.009	.036	-.024	
Post-CB NA	-.016	.018	-.105	
Post-CB NA x Task	.058	.025	.253*	

Note: NA = Negative Affect; CB = Cyberball. Negative affect was centered at its mean.
^ $p < .1$ * $p < .05$ ** $p < .01$

Because both age group and task interacted with post-Cyberball negative affect to predict the change in high-frequency-loss plays, we then tested a model for this outcome variable entering the 3-way interaction between negative affect, age-group, and task in step 5. The interaction term for negative affect x child vs other x task was a marginal predictor of change in high-frequency-loss plays (B = .06, β = .16, t = 1.78, p < .08), but did not add significant variance to the model (R^2-change = .023, p = .18), so we are cautious in interpreting this finding.

Discussion

The current study examined the extent to which acute peer ostracism increases negative affect and anxiety in children, adolescents, and adults, and whether reactions to ostracism influenced subsequent risky decision-making. The latter question was inspired by recent work suggesting that adolescents show increased risk-taking after being ostracized both acutely (Peake et al., 2013) and chronically (Telzer et al., 2014). We used a different risky decision-making task than previous studies, a modified Iowa Gambling Task, to examine whether previous findings would extend to a different incentive-based task. We also sought to determine whether the presence of social feedback in the decision-making task moderates any link between reactions to ostracism and risk-taking, a question that has not, to our knowledge, been examined by previous research.

Influence of Age on Reactions to Cyberball

Regarding the first question, we hypothesized that adolescents would show stronger negative emotional reactions to peer ostracism than children and adults based on previous work (Sebastian et al., 2010). Existing research has examined reactions to Cyberball ostracism in adolescents and adults, but not in children. We did not replicate findings that adolescents react more strongly to ostracism than adults; both adolescents and adults in this study showed an increase in negative affect and state anxiety following ostracism. Our adult sample was younger (mean age < 20 years) than the sample in the study by Sebastian et al (2010), which had a mean age of 28 years. Furthermore, Sebastian and colleagues tested all females, whereas the current included both males and females. Though we did not find differences in reactions to Cyberball based on sex (see appendix), it is possible that males and females respond differently to social exclusion. Finally, most of our adult participants were undergraduate students, and college is an environment in which peer relationships are arguably highly in flux, similar to the adolescent years. More work is needed to determine whether the heightened sensitivity to social information that characterizes adolescence (Nelson et al., 2005) might extend into young adulthood for individuals who attend college. Such work would also shed light on the extent to which biological versus environmental factors influence this sensitivity. Finally, our adult group reported higher levels of baseline state and trait anxiety than children and adolescents, which was opposite to the pattern found by Sebastian and colleagues. Individuals who are generally more anxious might also be expected to show stronger negative reactions to aversive social situations.

We did, however, find evidence of heightened negative reactions to ostracism in adolescence vs childhood, despite the fact that adolescents were less likely than children to believe they were playing with real-life peers in the Cyberball game. This finding parallels previous work suggesting that fears about negative evaluation by peers increase during the transition from childhood to adolescence (Westenberg et al., 2007). Although it is possible that children were simply less likely than adolescents to pick up on the fact that they were being ostracized during Cyberball, resulting in a more positive mood after the game, this explanation still fits with the notion that adolescents are more sensitive to social information, particularly regarding peers, than children are (Nelson et al., 2005).

Influence of Age, Task, and Reactions to Ostracism on Risk/Reward Behavior

Regarding links between ostracism and risk-taking on the gambling task, we hypothesized that more negative mood following peer ostracism would predict more risky decision-making uniquely in adolescents. Previous work has reported links between peer ostracism and risk-taking in adolescents (Peake et al., 2013; Telzer et al., 2014), but has not, to our knowledge, included child or adult comparison groups. In addition, these studies, in contrast to the current work, did not examine the influence of *reactions* to ostracism on risk-taking behavior. Our hypothesis regarding adolescents was supported, though our results suggest similar influences of negative affect following ostracism on gambling behavior in children and adolescents: even when controlling for baseline negative affect, at higher levels of negative affect following ostracism, both age groups increased risk-taking in the second round of the task relative to their age-matched peers: children increased their risk-taking more than peers and adolescents decreased their risk-taking less than peers. This pattern was especially pronounced when examining high-frequency-loss decks, i.e. the more "risky" decks. One interpretation of this finding is that children and adolescents who were more upset after being ostracized became somewhat desensitized to punishment on the second round of the gambling task, while adults showed the opposite pattern. In contrast to negative affect, we did not find significant main effects or interactions involving state anxiety, suggesting that mood ratings may have been a more sensitive measure of subjects' reactions to Cyberball.

We also predicted that links between ostracism-related negative affect and risk-taking would be more pronounced in a task with social feedback. Our results suggest, instead, that, for the risky, high-frequency-loss decks, the degree of ostracism-related negative affect predicted opposite patterns of behavior among subjects who completed the social versus non-social task. For the social task, regardless of age, individuals who seemed more upset after ostracism took slightly more risks relative to the first gambling task on these decks that dealt frequent punishment. For the nonsocial task, individuals who reported more negative affect took fewer risks, which is more consistent with predictions, at least for adult subjects. This result is surprising given that high-frequency-loss decks on the social task also yielded a high ratio of angry to happy faces. Possibly, subjects who were more upset about being ostracized and completed the social task were too distracted by negative social feedback (from both Cyberball and the gambling task) to learn which decks yielded frequent punishments on the second round of the task, and thus failed to avoid them. Another possibility is that these subjects became somewhat desensitized to negative social feedback and were less motivated to avoid it. Replication of the finding will be needed to determine the extent to which social feedback on a reward task influences behavior when individuals may feel socially threatened.

Limitations

Some important limitations of this study most be noted. The task we used, a modified IGT, is arguably more cognitively demanding, than other risky decision-making tasks, such as the BART and the Stoplight task, in that it requires learning about reward and loss contingencies among the decks. In addition, different risk-taking tasks may tap into different aspects of decision-making (Buelow & Blaine, 2015). Thus, future work will be needed to determine whether our findings generalize to other risk-taking tasks, let alone to real-world risk-taking behavior. In addition, we did not find effects of changes in state anxiety from pre- to post-ostracism, which could be due to lack of sensitivity in the measure. Changes in state were consistent, but subtle, and the structure of this measure (e.g., more items than the mood measure and a scale of only 1-3) may have encouraged individuals to respond similarly at both time points. A third limitation is that all subjects in this sample were ostracized; thus, it is possible that changes in decision-making from round 1 to round 2 of the gambling task were due to completing the task for a second time rather than to ostracism. By focusing on negative affect following ostracism as a predictor variable, controlling for baseline negative affect, we aimed to mitigate this interpretation. In addition, we did test a small group of adolescents (n=10) who were not ostracized during Cyberball, and these subjects also slightly reduced their risk-taking on the second round of the task, at a similar magnitude as ostracized adolescents. A fourth limitation is that our correlational analyses do not allow us to infer any causal directions of influence among the variables examined. Though we favor the interpretation that negative affect resulting from ostracism influenced risk-taking on the gambling task in different ways depending on age, one or more variables we did not measure, such as experience playing computer games or general engagement with the tasks, could explain these relationships. A final limitation is that we did not have the power to examine sex as a predictor variable. More research is needed here, as much of the research examining effects of peer ostracism in adolescence has included only females (e.g., Sebastian et al., 2010; Guyer et al., 2009).

Conclusion

The current study reveals important developmental differences regarding reactions to peer ostracism and the ways in which these reactions predict subsequent risk-taking in the short term. We report novel findings that adolescents show stronger negative emotional reactions to acute peer ostracism than children, supporting the notion that increased sensitivity to and concern about one's standing among peers undergoes a normative increase during the transition from childhood to adolescence. Our findings also parallel those of recent research suggesting that adolescents, in contrast to adults, engage in relatively more risk-taking when they feel socially threatened, and suggest that the same pattern occurs in younger children. Finally, our results highlight the complexity of the relationships between age, sensitivity to ostracism, and risk-taking. Certain phenomena, such as the effect of peer facilitation on risk-taking (e.g., Gardner &

Steinberg, 2005) may be unique to adolescence, but our findings suggest that certain tendencies traditionally thought to be adolescent-specific might extend down into childhood (increased risk-taking after social threat), while others might extend up into young adulthood (sensitivity to ostracism). The convergence of both increased sensitivity to social threat *and* relatively increased risk-taking in the context of social threat in adolescence, rather than either factor alone, may characterize the "storm and stress" as well as the potential for growth in this fascinating period of development.

Chapter 5: General Discussion

In this study, we examined interactions between development, risk- and reward-related behavior, anxiety, and social factors. Our focus was on adolescence, as this developmental period is characterized by converging changes in three key areas: sensitivity to social feedback, reward sensitivity, and increased risk for anxiety and depression. Previous developmental studies have examined one or two of these factors, but rarely all three together. The current study provides a comprehensive look at the transitions that characterize adolescence, and expands our understanding of the complex relationships among these factors across development. Below, I discuss our results in relation to current notions in the field: whether adolescents show increased reward sensitivity relative to adults and children, whether adolescents are more sensitive to social feedback than adults and children, and whether anxiety and social factors influence risk-taking.

Do Adolescents Take More Risks than Other Age Groups?

The dual systems (Steinberg, 2010) and maturational imbalance models (Casey et al., 2011) posit that risky behavior increases in adolescence due to a combination of heightened reward sensitivity and still-developing cognitive control. In contrast to many previous studies (Cauffman et al., 2010; Galvan et al., 2006), the current data do not support the notion that adolescents take more risks than children or adults on the task used in this study. When the task included social feedback, both adolescents and adults took more risks than children, but adolescents did not take more risks than adults in either condition.

There are several potential reasons for differences between our findings and those of others. First, our adolescent age group was relatively young (age 12-14); in the other study that used this task (Cauffman et al., 2010), which also included a larger sample, reward-seeking behavior was found to peak around age 16-18. Thus, it is possible that we missed the age window in which a peak in reward-seeking behavior on this particular task would occur. Related to this issue, most males in our sample reported that they were pre-pubescent. Puberty has been associated with increased reward-related brain activation in adolescence, even when controlling for age (Forbes et al., 2010). Given that nearly half of our sample had not yet entered puberty, we might not expect the dramatic adolescent-specific increase in reward sensitivity reported by some. In addition to these characteristics of our adolescent sample, our adult participants (mean age 19) were younger than in studies using community samples, close in age to the peak in reward-sensitivity reported by Cauffman et al (2010). We chose a younger, narrower adult age range to provide a more conservative test for the “uniqueness” of adolescents; if adolescents differed from individuals just a few years older, this would provide stronger evidence that biological processes such as pubertal maturation play a role in adolescent risk-taking. However, some of our younger adult participants may have been still at their "peak" reward sensitivity.

Our lack of significant findings regarding reward processing in adolescence also speaks to the importance of task and context when measuring reward-related behavior. Adolescents may exhibit heightened reward drive relative to other age groups in certain tasks, and in certain contexts, but not in others. One important factor may be the emotional salience of the reward. The task format and incentive (a $5 bonus for good performance) in this study may not have been emotionally salient enough to produce a significant age effect. In terms of context, other research has established that the presence of peers significantly increases risk-taking in adolescents but not in adults (Gardner & Steinberg, 2005). Although we included a form of social feedback in the social version of the gambling task, pictures of emotional facial expressions are likely less salient than real-life peers. Our null finding is an important reminder, though, that adolescents do not universally take more risks than other age groups.

Are Adolescents More Sensitive to Social Feedback than other ages?

Another important topic of investigation in this study was whether adolescents were more sensitive to social feedback than children and adults. We investigated developmental differences in reactions to 1) social stimuli on the gambling task and 2) social ostracism during Cyberball. Contrary to prediction, we did not find evidence for different risk-taking strategies in adolescents who completed the social versus non-social gambling task. The faces of unfamiliar non-peers may not have been salient enough to change adolescents' behavior in comparison to the incentives already built into the task (i.e., the goal to win more points/money was the same in both the social and non-social task). However, the data do show an interesting developmental trend across the three age groups, such that children who completed the social task reduced their risk-taking, adolescents played at the same level on both tasks, and adults who completed the social task *increased* their risk-taking. Due to the cross-sectional nature and between-subjects design of this study, we cannot rule out cohort effects in accounting for this trend. However, these results could speak to basic reward processing mechanisms unique to adolescence, such that while children and adults may have been distracted by social stimuli, adolescents remained focused on the task goal to win as many points as possible regardless of social feedback. Supporting this idea, the presence of incentives has been shown to improve cognitive control during an antisaccade task to a greater extent in adolescents than in adults (Hardin, Schroth, Pine, & Ernst, 2007). Similarly, in the current study, adolescents may have been more influenced by the task incentive than children and adults; while this incentive was not salient enough to result in more risky or impulsive decision-making in adolescents, its presence may have left fewer degrees of freedom for social stimuli to change their behavior.

We also examined participants' sensitivity to *negative* social feedback using the Cyberball ostracism task. Unlike a previous study (Sebastian et al., 2010) we did not find differences between adolescents and adults in negative affect ratings before vs after Cyberball; this may be due to our adult sample being younger, more anxious, and still in a college environment in which peer relationships are in flux. However, children showed less sensitivity to social ostracism than adolescents and adults, reporting little change in negative affect. This was the first study, to our knowledge, to examine reactions to Cyberball in younger children. There are several potential explanations for this finding.

Children may have noticed that peers stopped throwing them the ball, but not been particularly bothered by this. Another possibility is that children were less likely to notice they were excluded for a prolonged period of time (about 1 minute); if they were less bored by the task, the entire task (inclusion and exclusion) may have seemed shorter. A final possibility is that none of the age groups were particularly bothered after Cyberball, but that children experienced fewer demand characteristics to report that they were. To differentiate these possibilities, future work should more thoroughly investigate children's reactions to Cyberball using more follow-up questions (e.g., "how long did peers exclude you?") and more objective measures of affect (e.g., physiological or neural responses).

In sum, we did not find evidence that adolescents as a group were more sensitive to social feedback than adults or children based on behavior on the gambling tasks or reactions to ostracism. Our results, including unique developmental trends for the two aspects of social feedback measured, are an important reminder that context and task must be taken into account when studying the influence of "social stimuli," a term that can be interpreted in many different ways. In the current study, the social stimulus was the presence of non-familiar emotional faces, which clearly influence risk-taking in a different way than the presence of real-life peers, another type of social stimulus. The current study shows that children's decision-making may be *more* affected than that of adolescents by the stimulus of emotional faces during an incentive-based task, but that children are *less* emotionally affected by short-term ostracism by unfamiliar peers.

The Influence of Anxiety and Ostracism on Risk-Taking

A further goal of this study was to examine the influences of 1) anxiety and 2) ostracism on gambling behavior in children, adolescents, and adults. These domains are key in bridging links between increases in risk-taking, the influence of peer relationships, and internalizing problems that have been documented in adolescence. Previous work has found that anxious adults tend to be more risk averse, which can result in either impaired (Miu et al, 2008) or superior performance (Mueller et al., 2010) on incentive-based tasks. Links between anxiety and risk-taking in youth have rarely been studied, though some evidence suggests that depressed youth show decreased reward sensitivity (Forbes et al., 2006). In the current study, we examined the extent to which general and social anxiety predicted specific patterns of risk-taking across different types of decks. We found that adults who reported more generalized anxiety showed a strong tendency to play less than their peers from decks that gave infrequent, but large, losses, demonstrating aversion to large magnitude losses. This tendency in high-anxious adults was opposite to the trends among all other participants, who strongly favored the infrequent-loss decks over frequent-loss decks.

Children and adolescents, who were less anxious than adults, did not show this strong modulating effect of anxiety on the distribution of decks played. However, when age groups were examined separately, there was a trend for more socially anxious and trait-anxious adolescents to take more risks overall. In sum, there was little evidence for any effect of anxiety on gambling behavior in children, while anxiety predicted slightly increased risk-taking in adolescence, and strongly predicted avoidance of large magnitude losses (but not less playing overall) in adults. Thus, anxiety predicted quite different patterns of behavior in each age group. Although our participants were healthy and did not tend to score within the clinical range on anxiety measures, our findings suggest that we might expect different patterns of risk- and reward-related behavior to be linked to risk for anxiety disorder in different age groups: in contrast to adults, adolescents prone to anxiety might show signs of heightened risk-taking relative to peers (e.g., Reynolds et al., 2013).

In addition to trait aspects of anxiety, we predicted that feeling socially threatened would influence risk-taking, particularly with the social version of the gambling task. We used the Cyberball ostracism paradigm to induce feelings of social threat in our participants. A recent study (Peake et al., 2013) showed that adolescents who were ostracized during Cyberball subsequently took more risks on a simulated driving task relative to their risk-taking on the same task before ostracism, and that this increase was correlated with susceptibility to peer influence. In the current study, we used a similar paradigm but expanded the age groups tested, used a different risky decision-making task, and examined participants' emotional reactions (negative affect ratings and state anxiety) to the Cyberball task in relation to subsequent changes in risk-taking. Our results support the notion that adolescents take more risks relative to their peers when they feel socially threatened, showing that those who reported higher levels of negative affect after Cyberball increased their overall plays on the gambling task, playing more from high-frequency-loss decks in particular, relative to peers who reported lower levels of negative affect following ostracism. The data reveal a similar pattern among children, but suggest a trend in the opposite direction among adults. These findings suggest that youth may become desensitized to punishment (i.e., less risk averse) in the short-term after being ostracized, while adults become slightly more risk averse. The data also showed that this pattern among children and adolescents was more pronounced in the social gambling task, suggesting desensitization to negative *social* feedback in particular.

Others have hypothesized that, over time, social rejection leads to dampening of the reward system and reduced risk-taking, establishing a pathway to depression in adolescence (e.g., Davey et al., 2008). Our results do not support or contradict this notion, because we did not measure chronic peer exclusion in our participants. Yet, the tendency to increase exploration/risk-taking in the short-term following a perceived negative social experience could be adaptive for youth/adolescents, who need to adjust to rapidly changing social environments; e.g., if one is rejected by friends/playmates, it is adaptive to go out and find new friends/playmates. This tendency parallels the trend in the current data for more socially anxious adolescents to take more risks; i.e., both trait and ostracism-induced aspects of perceived social threat may promote exploration among youth. In contrast, among adults, for whom social groups may be more established, a tendency to become more risk-averse when one feels socially rejected may be the most adaptive strategy to repair existing relationships and avoid further stepping on others' toes.

Contributions and Implications

The current study contributes important scientific knowledge to the field regarding developmental changes in risk-taking behavior, sensitivity to social feedback, anxiety, and links between these factors. First, we utilized a novel version of the IGT that includes social feedback, and report data indicating developmental changes in behavior on this task. In particular, our data show that adolescents are *not* universally more risk-prone or more influenced by social feedback than children and adults. Instead, increased risky behavior and sensitivity to social stimuli among adolescents appears to be limited to specific contexts.

Second, we examined responses to Cyberball ostracism for the first time in 8- and 9-year-old children, and show that children this age show fewer negative emotional responses to ostracism than adolescents and adults. Our data suggest that negative responses to ostracism increase during the transition to adolescence and remain heightened into young adulthood. Given that interpersonal stress is linked to risk for internalizing disorders, our results suggest a potential explanation for why the risk for developing anxiety or depression increases during adolescence and remains heightened during young adulthood.

Third, we examined interactions between anxiety and risk-taking, and social ostracism and risk-taking in three age groups, the first time these interactions have been examined across a wide range of development. Our results suggest that both trait aspects of anxiety and negative affect resulting from ostracism differentially predict risky behavior in youth and adults. Broadly, in youth, these factors appear to lead to more approach behaviors in the context of risky decision-making while in adults they lead to more avoidance behaviors. Both trends may be adaptive in the context of age-based differences in the structures of peer groups.

Limitations and Future Directions

The current study generates many promising new directions for future research. One direction pertains to the development of a social risk-taking task. In the current study, we added to the IGT emotional faces with expressions congruent to the card outcome, but this task could incorporate social feedback in different ways—for example, the goal of the task could be changed to a more social one, such as winning approval from peers on a team—and this manipulation could result in quite different developmental trends than those we observed. Another direction pertains to measurements of mood and anxiety. We used self-report measurements (as parent-reports showed highly skewed distributions), but more objective measurements, such as skin conductance responses, cortisol levels, and neural activation patterns would be valuable. Often, these measures are more sensitive to group differences than self-reports (e.g., Will, van Lier, Crone, & Guroglu, 2015). An important limitation of self-report in developmental studies is the risk that different age groups interpret questions differently and/or the need to use different forms of a questionnaire to assess mood and anxiety for children and adults. We cannot rule out effects of these confounds in the current data. A third valuable direction for future research pertains to the need for longitudinal data addressing the issues studied here, or at least cross-sectional data with more continuous age ranges. Our cross-sectional data suggests shifts in certain factors, such as reactions to ostracism from childhood to adolescence and changes in links between anxiety and risk-taking from adolescence to young adulthood, but we cannot rule out cohort effects or pinpoint precisely when such shifts might occur.

Conclusion

This study examined interactions among several factors—risk and reward sensitivity, reactions to social feedback and ostracism, and anxiety—that may contribute to both increased risky behavior and increased risk for internalizing problems in adolescence. We compared adolescents to both younger and older age groups, which few studies have done. We did not find evidence for any single factor—i.e., general risk-taking or sensitivity to social information—that stood out in adolescents compared to both children and adults. However, relative to children, adolescents did show heightened risk-taking on a social gambling task and sensitivity to social ostracism; relative to adults, adolescents showed a positive link between ostracism-related negative affect and risk-taking. This convergence of developmental trends may help to explain some unique patterns of behavior observed in adolescents, such as increased risk-taking, susceptibility to peer influence, and struggles with anxiety and depression. In sum, this study indicates that factors related to risky behavior and internalizing problems in adolescence may overlap, and that this rich topic warrants future investigation.

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Appendix 1: Effects of Sex and Pubertal Development on Decision-Making, Mood, and Anxiety

Our primary between-subjects variables-of-interest in this study were age group and gambling task condition. We did not have sufficient power to examine the effects of sex or puberty in conjunction with these variables. In this appendix, we conducted exploratory analyses investigating the effects of sex, puberty, and sex x age interactions on the following variables (described in previous chapters): gambling behavior in round 1, anxiety measures, and negative affect in response to Cyberball.

There is reason to believe that sex and pubertal status might influence these outcome measures in the current study. For example, the literature suggests that females are more likely to experience anxiety and depression than males (e.g., Sontag & Graber, 2010); an open question is whether they are also more sensitive to social rejection or ostracism. Interestingly, several studies examining reactions to social rejection in adolescents have included only female participants (e.g. Guyer et al., 2009; Sebastian et al., 2010b), so it is unclear from existing research whether adolescent boys show the same sensitivity as girls to social rejection. Adolescent girls do tend to report more interpersonal stress and greater concern about peer evaluation than their male peers (La Greca & Lopez, 1998). From early in development, females also tend to be more sensitive to emotional cues than males—for example, they recognize facial expressions of emotion more easily (Nolen-Hoeksema, 2012). In adolescence, this advantage might predispose them to "read into" others' behavior to a greater extent than males, potentially increasing girls' awareness of peer rejection. In addition, girls tend to experience more relational aggression than boys throughout childhood (Crick & Grotpeter, 1995).

Risk-taking is another outcome that appears to be influenced by sex. Greater risk taking in males than females has been observed across a wide range of behaviors, including investment decisions (Sunden & Surette, 1998), rates of alcohol abuse (Hill & Chow, 2002), and motor vehicle accidents (Maxim & Keane, 1992). In parallel with real-world risk-taking, sex differences in decision-making have also been found in laboratory tasks. For example, one study (d'Acremont &Van der Linden, 2006) found that adolescent girls, but not boys, learned to play less from risky decks during the Iowa Gambling Task, resulting in more advantageous decisions. This finding suggests that adolescent females may be more risk avoidant than males during incentive-based decision-making tasks.

It is also well known that puberty widens the degree of biological differences between males and females in adolescence. From rodent models, we have learned that social behaviors appear to be particularly susceptible to environmental influences during puberty; for example, pubertal hormones have been shown to play an organizing role in establishing patterns of peer interactions in rats (Primus & Kellogg, 1990). Broadly, puberty may play a role in shifting family-oriented behavioral patterns to be more peer-oriented to promote reproduction in adolescence (Nelson et al., 2005). However, we know little about how puberty affects behavior in humans, in part because the best ways to measure puberty are not always clear (Blakemore, Burnett, & Dahl, 2010). Preliminary work does suggest that increases in sensation seeking tend to correlate more with puberty than with chronological age (Steinberg, 2008). In addition, parallel changes in adolescent behavior among rodents and humans (increased engagement with peers, newfound interest in opposite-sex individuals, increased reactivity to social stress) suggest that pubertal hormones may have similar effects on social behavior in both species.

Based on prior research, we hypothesized that, in the current study, 1) females would show more anxiety than males; 2) females would make fewer risky decisions than males, and 3) among adolescents, pubertal development would predict higher risk-taking.

Measures

To measure puberty, adolescent participants completed the Physical Development Scale (PDS) (Petersen, Crockett, Richards, & Boxer, 1988), a 5-item self-report questionnaire that asks children to rate their development of primary and secondary sex characteristics. Boys and girls completed separate forms.

Results

Interactions between sex and puberty

Before examining the separate influences of biological sex and puberty, we determined the extent to which these factors were correlated, given that girls tend to go through puberty earlier than males. A one-way ANOVA testing mean score on the Physical Development Scale indicated that female adolescents in our sample were significantly more advanced in their pubertal development ($F(1.56) = 24.75$, $p < .001$) than males. A chi-square analysis testing the distribution of categorical puberty scores (pre-pubertal, early puberty, and late puberty) indicated that girls were more likely than boys to be in late puberty, whereas boys were more likely than girls to be prepubescent ($X^2(2) = 26.5$, $p < .001$).

Effects of Sex and Sex x Age Interactions on Anxiety

We performed a series of 2 (sex) x 3 (age group) ANOVAs examining state anxiety at baseline, trait anxiety, and social anxiety. Sex was a significant predictor of social anxiety only ($F(1, 155) = 5.69$, $p < .02$), with females reporting higher levels of social anxiety ($M = 42.6$) than males ($M = 38.0$) across age groups. As discussed previously, adults reported higher levels of social anxiety than children and adolescents, but there was no significant age x sex interaction.

Effects of Sex and Sex x Age Interactions on Reactions to Cyberball

Females might report higher levels of social anxiety because they are more sensitive to ostracism than males. To investigate whether females were more sensitive to ostracism, we performed two 2 (sex) x 3 (age group) x 2 (time; baseline and post-Cyberball) repeated measures ANOVAs examining negative affect and state anxiety. Neither of these tests indicated significant main effects or interactions involving sex. Thus, females did not react differently than males to this short-term ostracism scenario.

Effects of Sex and Sex x Age Interactions in Gambling Task Behavior

We then turned to the gambling task, to examine whether males were more likely than females to play from risky decks. To investigate this, we conducted a series of 2 (sex) x 3 (age-group) ANOVAs to investigate first, the total proportion of plays, and then advantageous plays, disadvantageous plays, high-frequency loss plays, and low-frequency loss plays from the first gambling task. There were no significant main effects of sex, but there was a significant interaction between age group and sex for total proportion of plays ($F(2, 156) = 5.26$, $p < .01$). This interaction was not specific to a certain deck type, predicting also advantageous, disadvantageous, and high-frequency loss plays, but not low-frequency loss plays (individuals in all groups tended to favor these decks). This interaction resulted from sex predicting opposite patterns of behavior among children and adolescents (see Figure A.1). Follow-up simple effects tests showed that, among children, males played more across the board than females ($F(1, 48) = 4.57$, $p < .04$), whereas among adolescents, females played more than males ($F(1,57) = 5.8$, $p < .02$). Among adults, males and females did not differ in their proportion of plays.

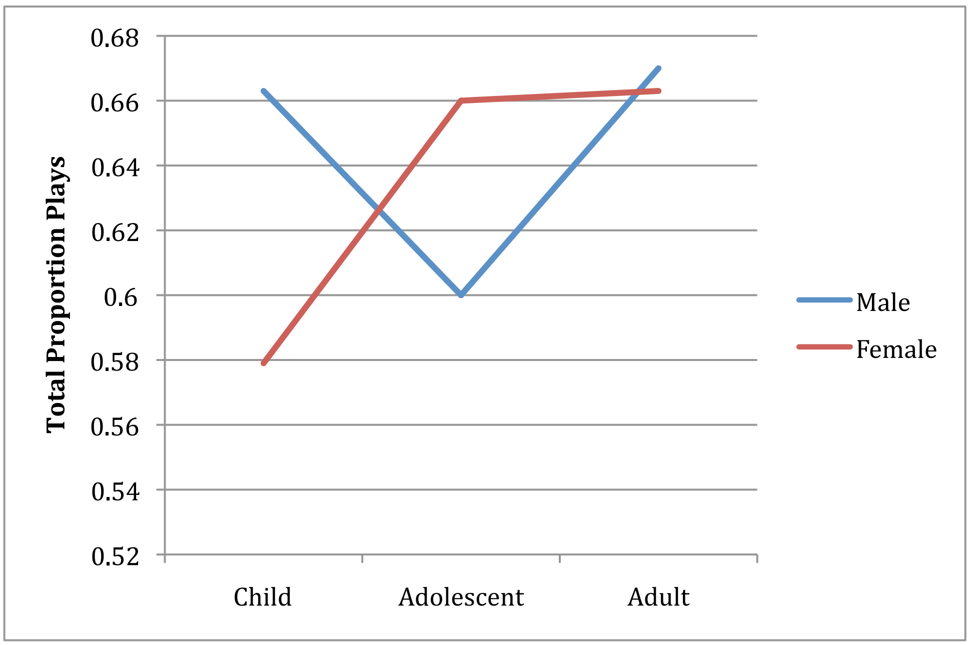

Figure A.1. Age x Sex Interaction for Total Proportion of Plays

Effects of Puberty

We also examined the effects of pubertal development among adolescents on all the above variables with Pearson correlations, using the mean score on the Peterson scale. None of these correlations were significant, indicating that pubertal development was not a meaningful predictor of our outcome variables in this sample.

Discussion

Based on previous research, we had predicted that females would show more anxiety than males across age groups. This hypothesis was confirmed for social anxiety, though not generalized (state or trait) anxiety. Social anxiety is a significant predictor of later depression, and is especially likely to be comorbid with depression (e.g., Beesdo et al., 2007). Thus, higher levels of social anxiety in females as young as age 8 in the current study may help to explain the higher lifelong prevalence of depression in females (Sontag & Graber, 2010). We did not, however, find any sex differences in reactions to Cyberball. This task is a relatively mild, and very short-term simulation of ostracism; in addition, subjects played with unfamiliar peers rather than people they knew. In the real world, ostracism tends to be more chronic, and to occur among friends or acquaintances. It is possible that females do tend to more frequently encounter and/or show more negative reactions to such experiences, conferring higher risks of social anxiety and depression.

We also predicted that females would make fewer risky (i.e., “play”) decisions on the gambling task than males based on previous work (d'Acremont &Van der Linden, 2006). Our hypothesis was confirmed among 8-9-year-old children, which to our knowledge is a novel finding, as few studies have examined children’s behavior on this type of decision-making task. The only published study that used this play vs pass format of the IGT (Cauffman et al., 2011) included children only as young as 10-11 only; our finding for 8-9-year-olds parallels their results for adults *and* children, that males tended to play more across the board than females. We did not, however, find that adolescent or adult males took more risks on this task than females. In fact, adolescent females took *more* risks than males. This interesting finding requires further investigation and replication. Adolescent females in our sample were more advanced in pubertal development than males, and puberty is another factor that may increase risky behavior (Steinberg, 2008). Though we did not find that pubertal development was correlated with gambling behavior, future work should compare boys and girls at equivalent levels of puberty on similar decision-making tasks to replicate this finding. In terms of differences between children, and adolescents, we cannot rule out cohort effects given the cross-sectional design of this study. In our sample, female children and male adolescents showed decreased risk-taking compared to other groups. Future work should investigate whether these trends hold using longitudinal designs.

In sum, we found that females are more socially anxious than males, but did not react differently to short-term ostracism, and that age interacted with sex to predict overall risk-taking on the gambling tasks. Pubertal development did not predict any outcome variables. Ideally, future work will utilize longitudinal designs to further articulate how interactions between age, sex, and puberty influence risky decision-making, internalizing symptoms, and reactions to experiences with peers.

Appendix II: Questionnaires

In addition to the questionnaires below, subjects completed the State-Trait Anxiety Scale (adults) or State-Trait Anxiety Scale for children (Spielberger et al., 1983)

Moods and Feelings Questionnaire (completed at baseline, after gambling task 1, and after Cyberball)

We would like to know how people react to each of these games and how they change people's moods. Please circle the number that best describes how you feel Right Now.

1.
1 2 3 4 5 6 7
Good Bad

2.
1 2 3 4 5 6 7
Tired Full of Energy

3.
1 2 3 4 5 6 7
Happy Sad

4.
1 2 3 4 5 6 7
Friendly Unfriendly

5.
1 2 3 4 5 6 7
Tense Relaxed

6.
1 2 3 4 5 6 7
Confident Unsure

7.
1 2 3 4 5 6 7
Frustrated Content

Game Reactions Questionnaire (after gambling task and after Cyberball)

We would like to know how people feel about these games so we can make them more fun. Please circle the number that best describes how you felt about the game.

1. I liked this game:

1	2	3	4	5	6	7
Not at all						A lot

2. I felt like I had control over how the game went:

1	2	3	4	5	6	7
Not at all						A lot

3. I felt good about myself during the game:

1	2	3	4	5	6	7
Not at all						A little

4. This game seemed:

1	2	3	4	5	6	7
Boring						Exciting

5. This game seemed:

1	2	3	4	5	6	7
Easy						Hard

6. I would like to play this game again:

1	2	3	4	5	6	7
Not at all						A lot

For Cyberball:

6. I would like to play this game again with the same players:

1	2	3	4	5	6	7
Not at all						A lot

7. I would like to play this game again with different players:

1	2	3	4	5	6	7
Not at all						A lot

Social Experiences Questionnaire (La Greca & Lopez, 1998)

Directions: Read each statement below. Please circle the number of the choice that best describes how you generally feel:
1 = Not at all
2 = Rarely
3 = Sometimes
4 = Often
5 = All the time

Do not circle more than one number or leave any items blank. There are no right or wrong answers, so please be honest in your answers.

1. I worry about doing something new in front of others.
2. I worry about being teased.
3. I feel shy around people I don't know.
4. I only talk to people I know really well.
5. I feel that peers talk about me behind my back.
6. I like to do activities with other people.
7. I worry about what others think of me.
9. I'm afraid that others will not like me.
10. I get nervous when I talk to peers I don't know well.
11. I worry about what say about me.
12. I get nervous when I meet new people.
13. I worry that others don't like me.
14. I am quiet when I'm with a new group of people.
15. I feel that others make fun of me.
16. If I get into an argument, I worry that the other person will not like me.
17. I'm afraid to invite others to do things with me because they might say no.
18. I feel nervous when I'm around certain people.
19. I feel shy even with peers I know very well.
20. It's hard for me to ask others to do things with me.